AEDsys Program

User Guide

Version 3.1

May 17, 2003

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1. GENERAL DESCRIPTION OF PROGRAM

The program **AEDsys** is based on the design tools in Chapters 2 through 7 of the AIAA Education Series textbook *Aircraft Engine Design, Second Edition* by Mattingly, Heiser, and Pratt. This program was written to facilitate engineers and students to perform the repetitive calculations and sensitivity studies inherent in aircraft engine conceptual design. The program has fourteen (14) constraint types, eight (8) contour plots, thirteen (13) mission types, seven (7) aircraft drag models, seven (7) engine thrust models, and seven (7) engine fuel consumption (TSFC) models. This program can perform the following analyses:

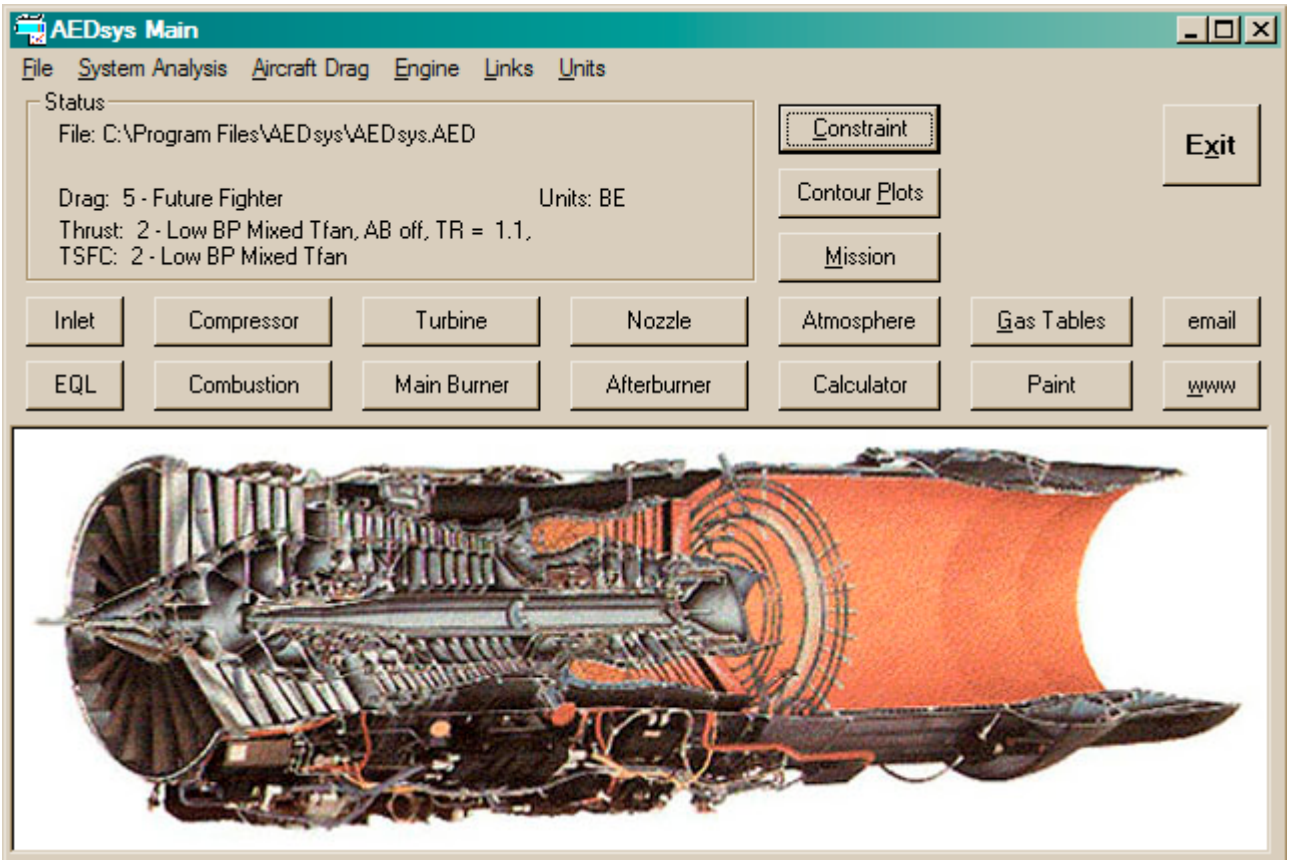
a. Constraint analysis.
b. Contours of aircraft/engine performance.
c. Mission analysis.
d. Engine performance analysis.

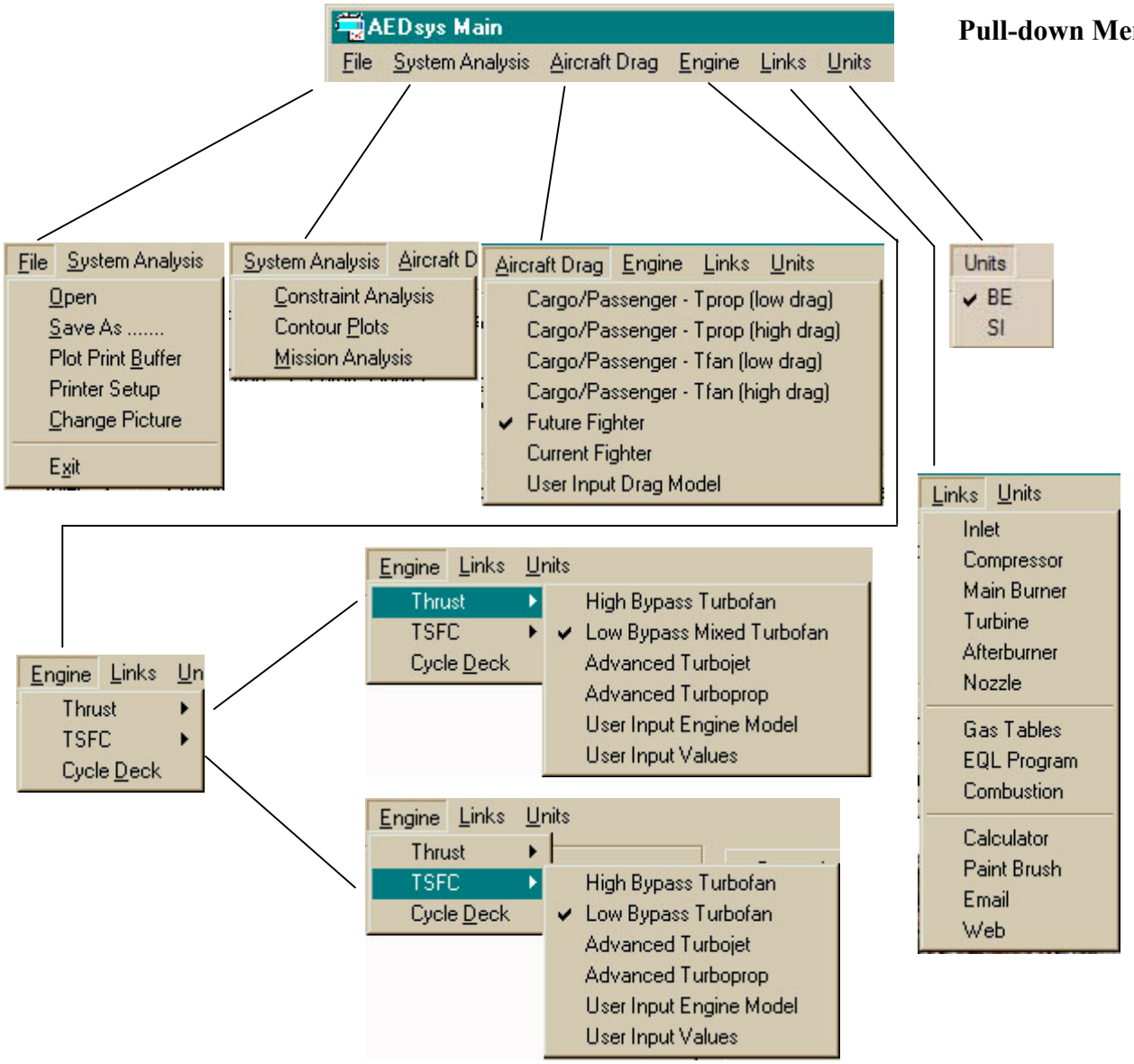
Data windows with input data fields show the user what input data is needed to perform each set of calculations.

Plotting of results is incorporated into each analysis using the Olectra Chart 6.0 software package. Plots can be custom-tailored and printed. Screens can be saved/printed by first pressing the **Alt** and **PrtSc** buttons at the same time (this captures a bit map of the current window onto the clip board); start the **Paint** program and paste the image from the clip board onto the blank screen; and then save/print the image.

2. MAIN WINDOW

When the AEDsys program is started, the default input data file (AEDsys.aed) is read and the main window is displayed as shown below. The pull-down menu system and push buttons help navigate the user. The pull-down menus are shown on the next page.





File Pull-down Menu

Many of the file pull-down menu functions are similar to that of other programs.

Open - Display a dialog window to open **AEDsys** input files (extension "aed").

Save As - Display a dialog window to save the current data file as an AEDsys data file. The default data file (AEDsys.aed) can be replaced with the current data by saving the file as AEDsys.aed.

Plot Print Buffer - High resolution constraint and contour plots can use significant printer buffer memory while being generated. If the user is connected to a printer by a network and not limited by the network setting, opening the printer buffer allows the user to select to print the plot generated by the Constraint Window's **Plot** button and the plot generated by the Contour Plot Data Window's **Plot Contour Lines** button.

Printer Setup - Display printer setup window.

Change Pictures - Open a dialog window to select and replace current picture (jpg or bmp) on Main Window.

Exit - Exit program.

System Analysis Pull-down Menu

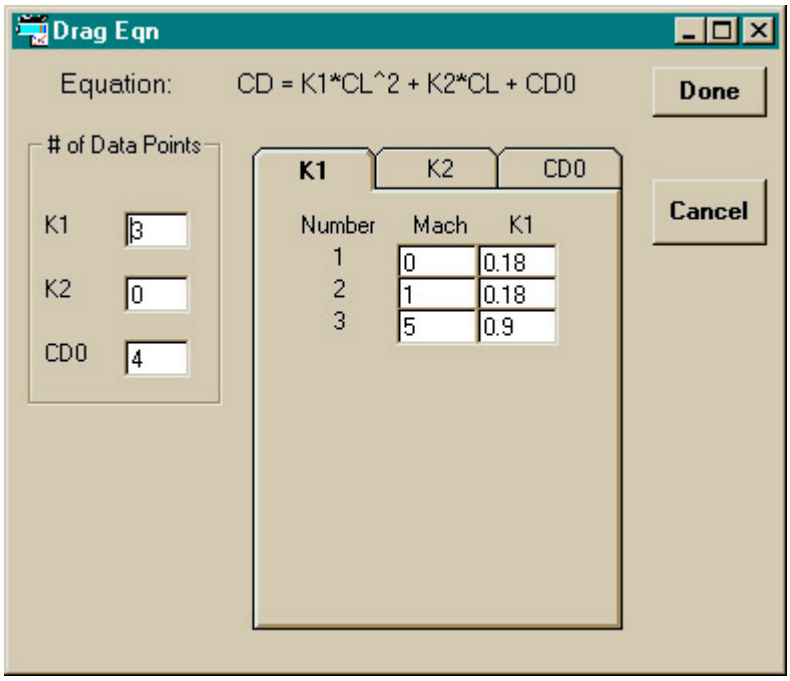
Provides links to the Constraint Analysis, Contour Plot, and Mission Analysis portions of the program. The user can also navigate using the Constraint Analysis, Contour Plot, and Mission Analysis buttons on the Main Window.

Aircraft Drag Pull-down Menu

User can select from seven (7) drag models. The first six models correspond to the data in the *Aircraft Engine Design, Second Edition.* The $C_{D\min}$ variation with Mach number for the first four drag models are as shown in the textbook. The program uses the following data for K'', $C_{L\min}$, AR, and e.

No.	Description	K''	$C_{L\min}$	AR	e
1	Cargo/Passenger - Tprop (low drag)	0.001	0.1	10	0.85
2	Cargo/Passenger - Tprop (high drag)	0.03	0.3	7	0.75
3	Cargo/Passenger - Tfan (low drag)	0.001	0.1	10	0.85
4	Cargo/Passenger - Tfan (high drag)	0.03	0.3	7	0.75

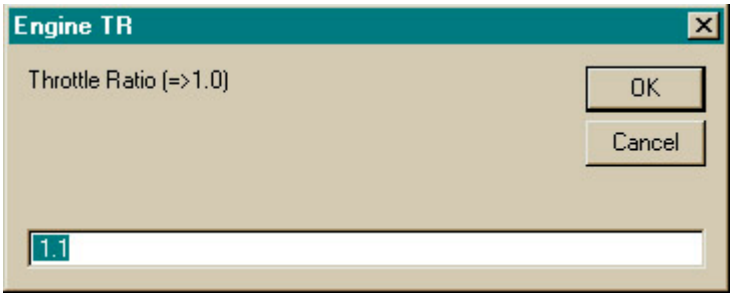
User selection of **User Input Drag Model** opens the following Drag Eqn Window that allows input of drag data versus Mach number. The maximum number of data points for each of the three drag coefficients is eleven (11). The Mach numbers must be entered in increasing value.



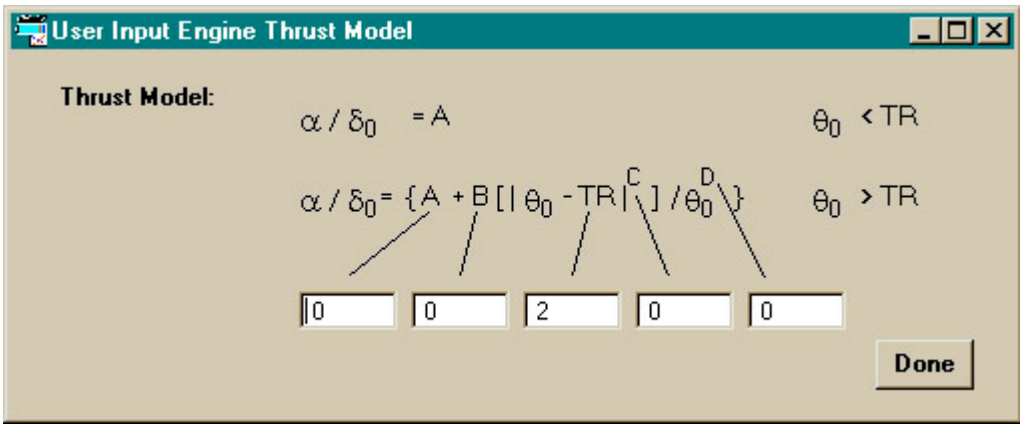
Engine Pull-down Menu

The user can choose from the basic **Thrust** and **TSFC** models of Chapters 2 and 3, respectively, or the **Cycle Deck** that uses the performance engine models of Chapter 5. When **Cycle Deck** model is selected, the **Engine Data Window** is opened for input of an engine reference data file generated by the ONX program.

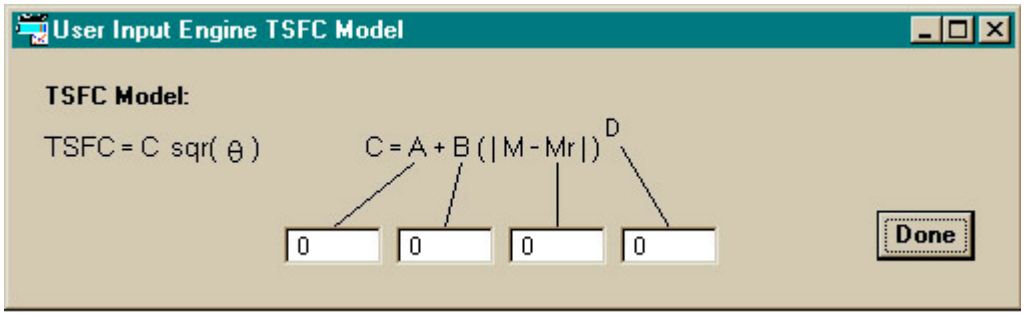
When **Thrust** is highlighted, the user can select from seven (7) basic thrust models. The first four (4) models correspond to the models in Section 2.3.2. When one of these four thrust models is selected, the Throttle Ratio (TR) window opens for user input.



When the **User Input Engine Model** is selected (model 5), the window opens for data input as shown below. When the **User Input Values** model is selected (model 6), a data field is created in the respective constraint analysis for user input of the thrust lapse (α) for that constraint. When **Cycle Deck** model is selected, the Engine Data Window is opened for input of an engine reference data file generated by the ONX program.



User can select from six (6) basic **TSFC** models. The first four (4) models correspond to the models in Section 3.3.2 of *Aircraft Engine Design, Second Edition*. When the **User Input Engine Model** is selected (model 5), the following window opens for data input.



Links Pull-down Menu

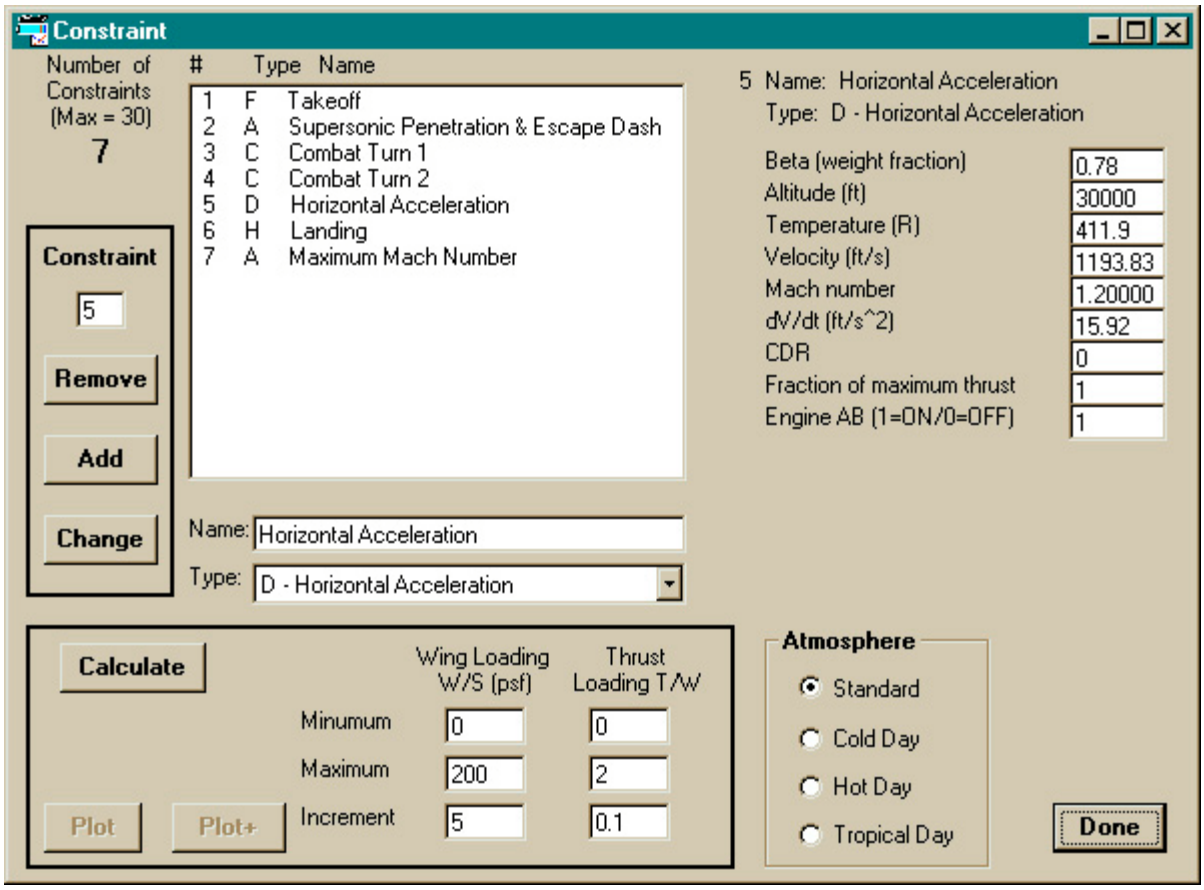
Provides links to the associated AEDsys software programs.

Units Pull-down Menu

The user can select British English (BE) or SI unit systems. When unit system changes, the data are converted to the new unit system.

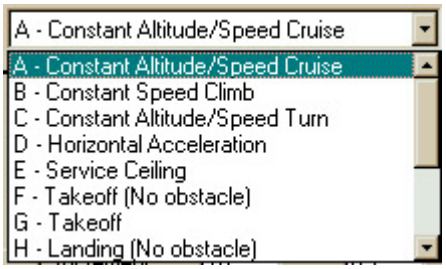
3. CONSTRAINT ANALYSIS

When either the **Constraint Analysis** button or the corresponding pull-down item in the System Analysis menu is selected, a Constraint Window is displayed like that shown below.



The constraints of interest can be constructed using the upper portion of this window. Double-clicking on an item in the upper left window causes the data for that constraint to be displayed on the right side of the window for editing.

The constraint analysis can model each of the fourteen (14) constraints of the textbook. The type of constraint is selected using the combo-box beside **Type** in the middle left of the window. Pressing the down arrow on the right edge of the box displays a list of constraint types for user selection as shown below (if needed, the user can scroll to the desired constraint).

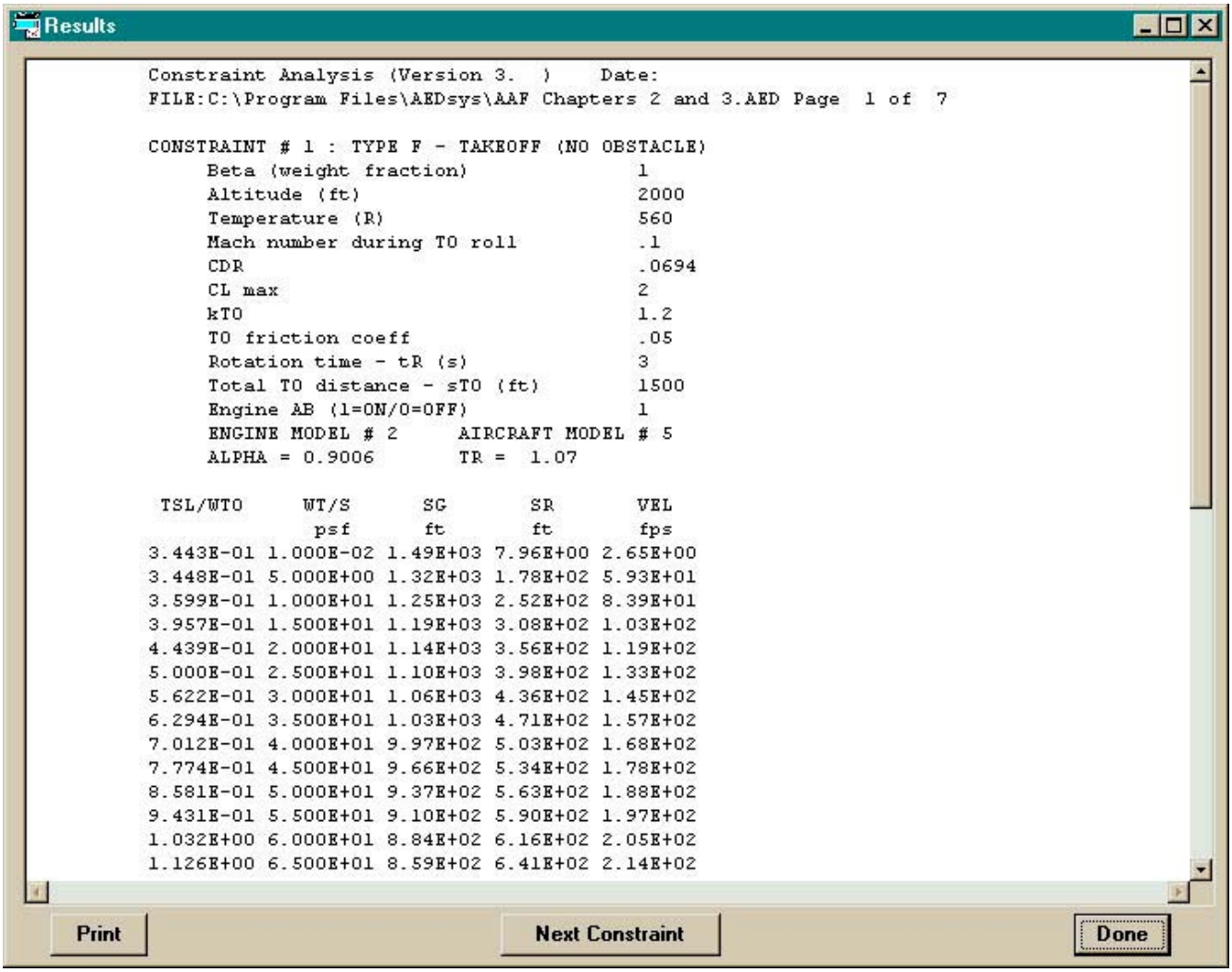

A - Constant Altitude/Speed Cruise
A - Constant Altitude/Speed Cruise
B - Constant Speed Climb
C - Constant Altitude/Speed Turn
D - Horizontal Acceleration
E - Service Ceiling
F - Takeoff (No obstacle)
G - Takeoff
H - Landing (No obstacle)

I - Landing
J - Acceleration Time
K - Takeoff Climb Angle
L - Carrier Takeoff
M - Carrier Landing
N - Carrier Approach

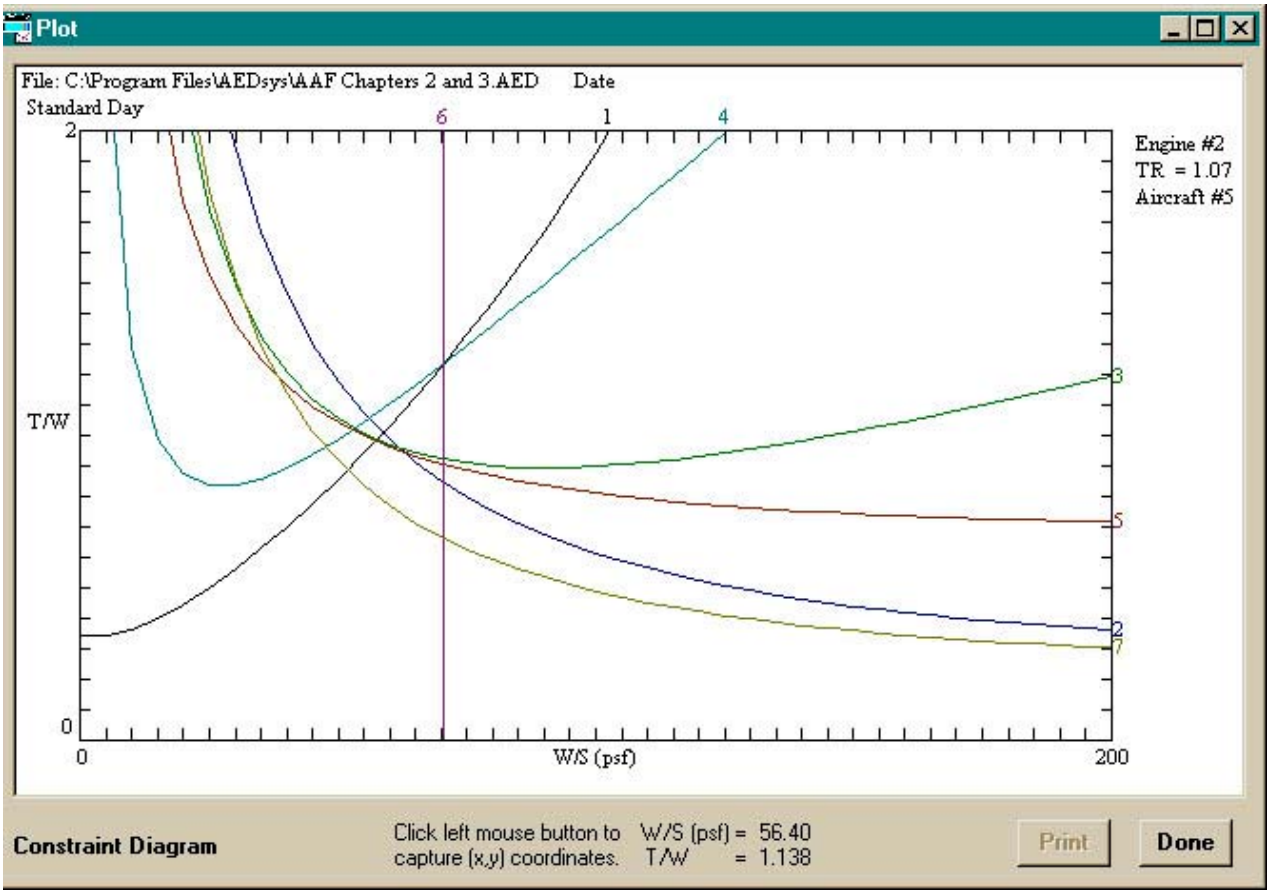
After a new constraint type is selected, the user presses the **Change** button to change the current constraint and the appropriate data list is shown on the right. Press the **Add** button to add a new constraint at the current constraint number. Press the **Remove** button to remove the current constraint.

The **Atmosphere** radio buttons allow the user to specify the atmospheric model that is to be used for auto-update of the air temperature for new altitude data. For flight conditions corresponding to one of these atmospheric models, enter the altitude first and then enter the desired temperature.

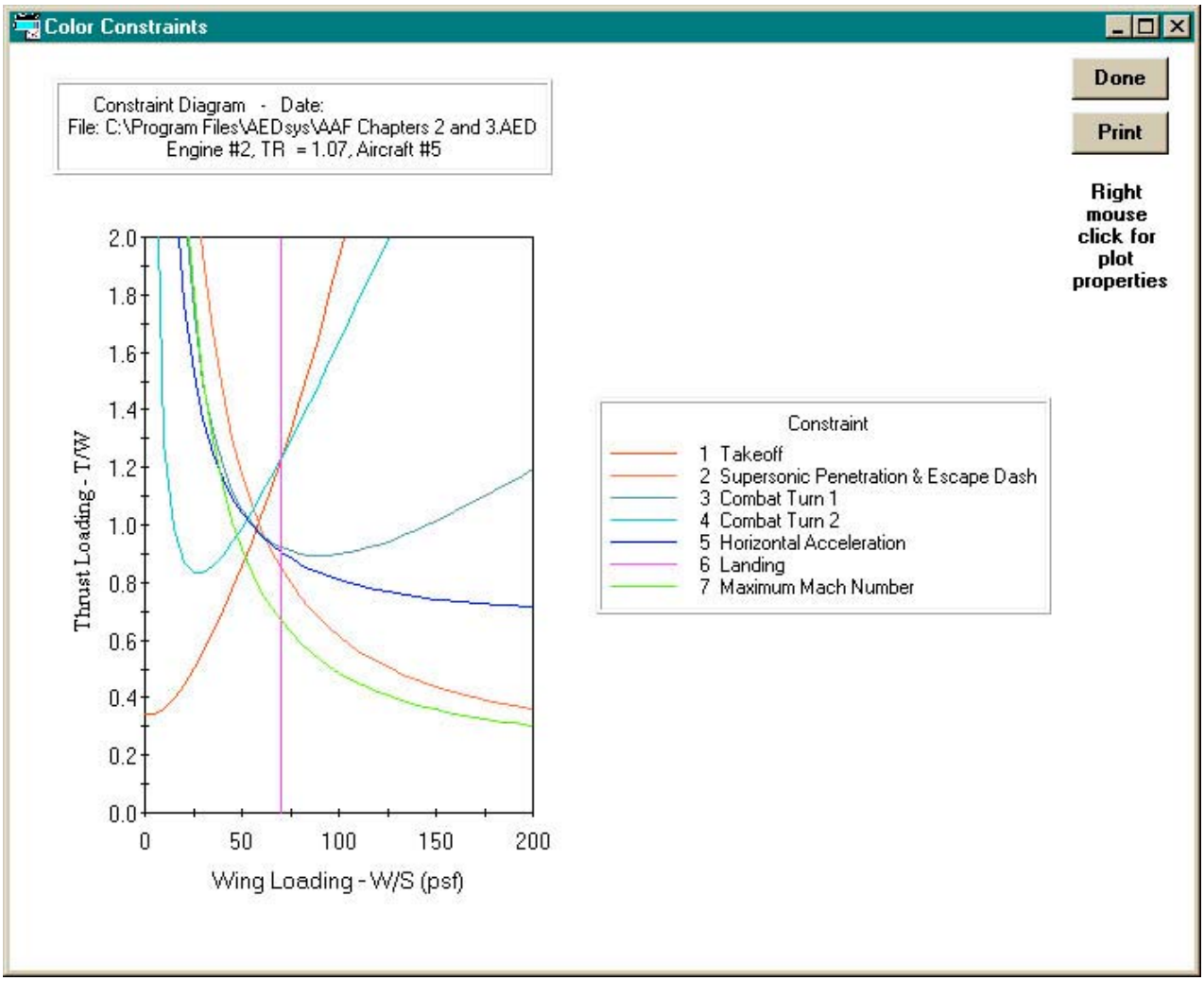
After entry of the ranges of wing loading and thrust loading, pressing the **Calculate** button opens the results window with the results for the first constraint as shown below. Pressing the **Print** button at the bottom of the Results window sends a copy of that constraint's results to the printer After at least one constraint has been calculated, the **Plot** and **Plot+** buttons are enabled.



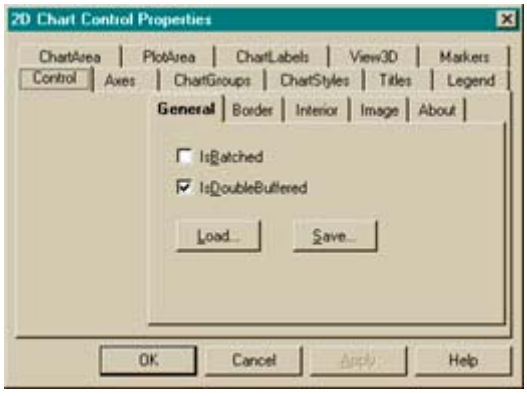
Pressing the **Plot** button displays the Plot window containing a basic plot of the constraints calculated with each constraint line numbered in accordance with its number in the Constraint window. This plot has a mouse-activated coordinate capture to facilitate reading the boundaries of the "solution space." An example plot is shown on the next page with the coordinates of the location of the mouse cross-hairs location captured and displayed below the plot.



Pressing the **Plot+** button opens the Color Constraint window with a plot of the constraint lines generated by the Olectra Chart plotting software. The user can select to show the plot legend, as done below, or generate a larger plot.

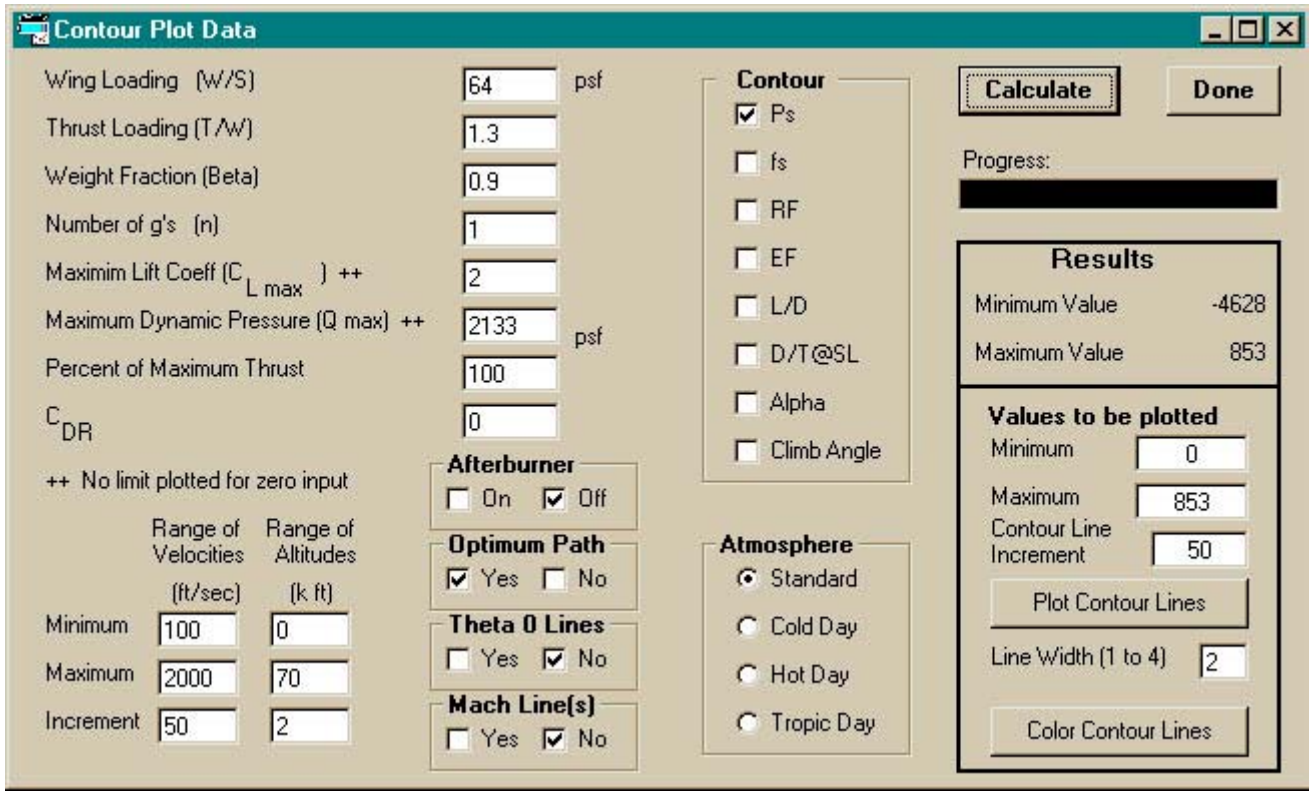


The layout of the plot (e.g., the color of the lines and location of the legend) can be changed by moving the mouse over the plot and pressing the right mouse button to display the plot properties (2D Chart Control Properties) window.



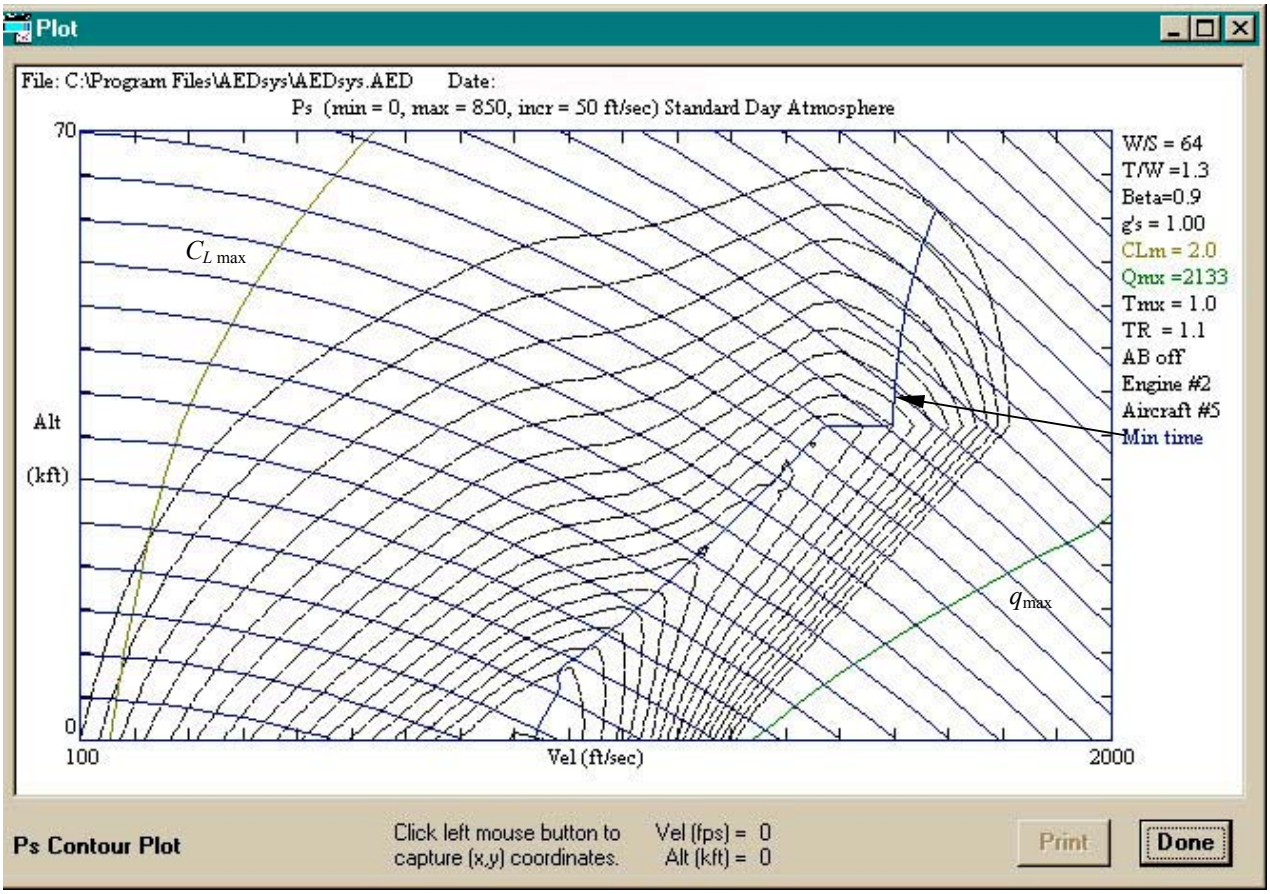
4. CONTOUR PLOTS

When either the **Contour Plots** button or the corresponding pull-down item in the System Analysis menu is selected, the Contour Plot Data Window is displayed like that shown below. This program feature allows the user to generate eight (8) different contour plots and display them in two (2) different plot formats. Calculations are performed at the wing loading (W_{TO}/S), thrust loading (T_{SL}/W_{TO}), weight fraction (β), and number of g's (n - load factor) over the range of altitudes and velocities using the selected altitude model. After the contour plot data has been calculated, the **Plot Contour Lines** and **Color Contour Lines** buttons are enabled. The user can enter the desired minima, maxima, and plot increments.

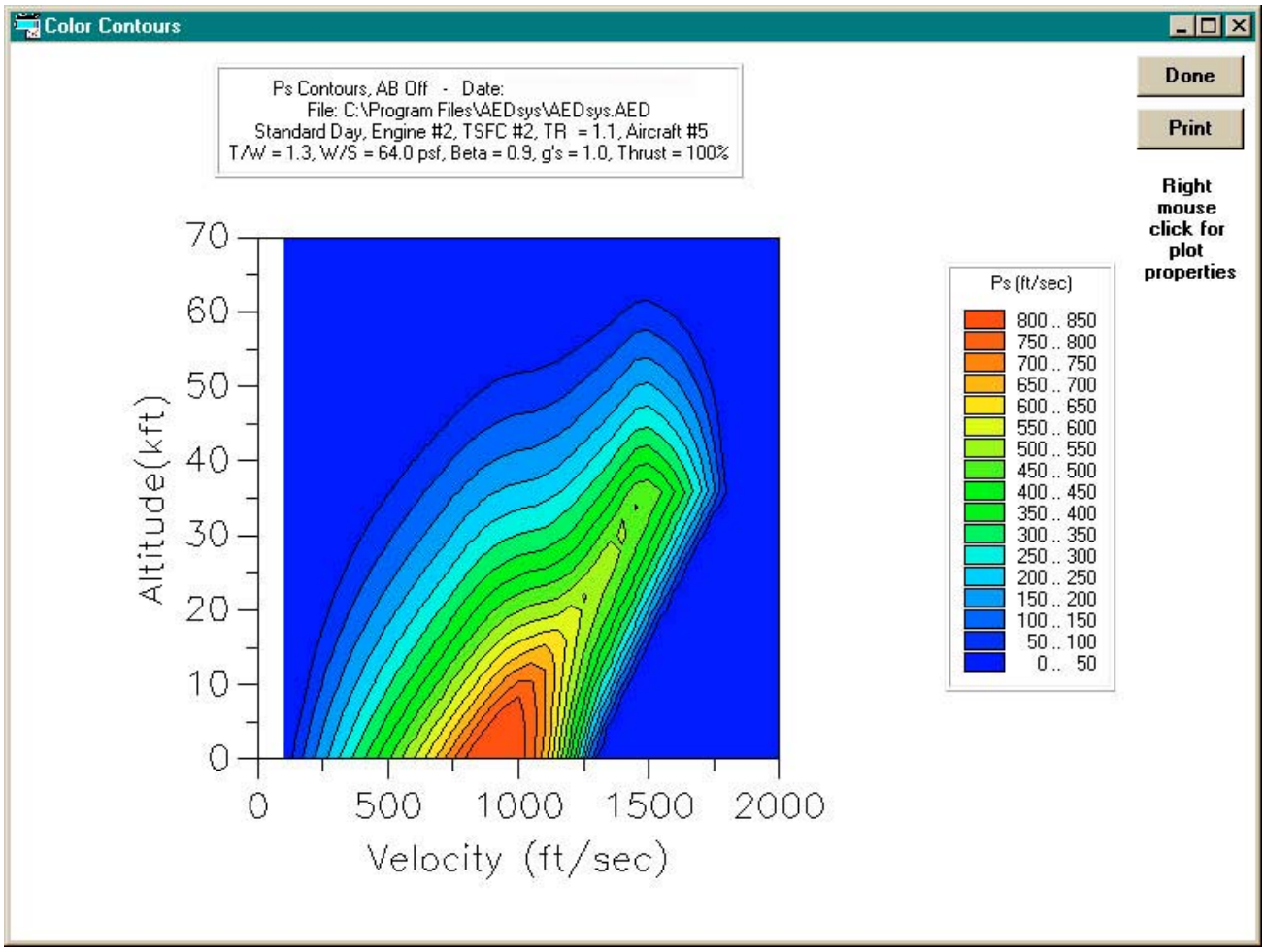


Pressing the **Plot Contour Lines** button results in the basic contour plot being generated in the Plot window as shown on the next page. This plot format will also show the maximum dynamic pressure (q), maximum lift coefficient (C_{Lmax}), optimum path, theta zero (θ_0) lines, and Mach lines when selected to be shown. The basic plot on the next page shows the maximum dynamic pressure, maximum lift coefficient, and minimum time-to-climb path on a P_s plot. Two labels and an arrow have been added to highlight these lines. Similar to the basic constraint plot, this plot has a mouse-activated coordinate capture to facilitate reading the data of the contour plot.

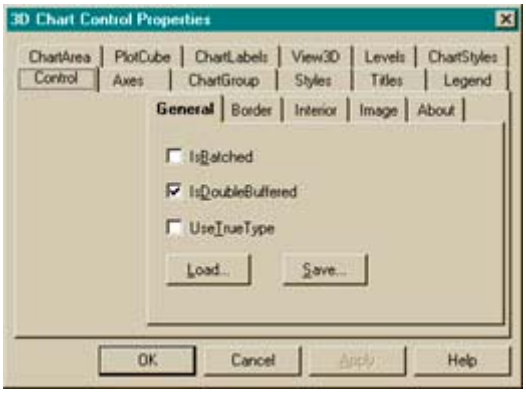
Contour	Description	Textbook Ref.	Optimum Path
Ps	Weight specific excess power (P_s)	Pg. 22, 48	Minimum time-to-climb
fs	Fuel consumed specific work (f_s)	Pg. 59, 92	Minimum fuel-to-climb
RF	Range factor (RF)	Pg. 65	Maximum L/D
EF	Endurance factor (EF)	Pg. 66	Maximum L/D
L/D	Lift-to-Drag ratio		Maximum L/D
D/T@SL	Drag-to-Thrust at SLS (D/T_{SL})		Maximum L/D
Alpha	Thrust lapse (α)	Pg. 23, 38	N/A
Climb Angle	θ	Pg. 33	N/A


Plot
File: C:\Program Files\AEDsys\AEDsys.AED Date:
Ps (min = 0, max = 850, incr = 50 ft/sec) Standard Day Atmosphere
70
0
Alt
(kft)
100
Vel (ft/sec)
2000
$C_{L\,max}$
q_{max}
W/S = 64
T/W =1.3
Beta=0.9
g's = 1.00
CLm = 2.0
Qmx =2133
Tmx = 1.0
TR = 1.1
AB off
Engine #2
Aircraft #5
Min time
Ps Contour Plot
Click left mouse button to capture (x,y) coordinates.
Vel (fps) = 0
Alt (kft) = 0
Print
Done

Pressing the **Color Contour Lines** button opens the Color Contours window with a plot of the contours generated by the Olectra Chart plotting software. This plot format is only able to show the contours.

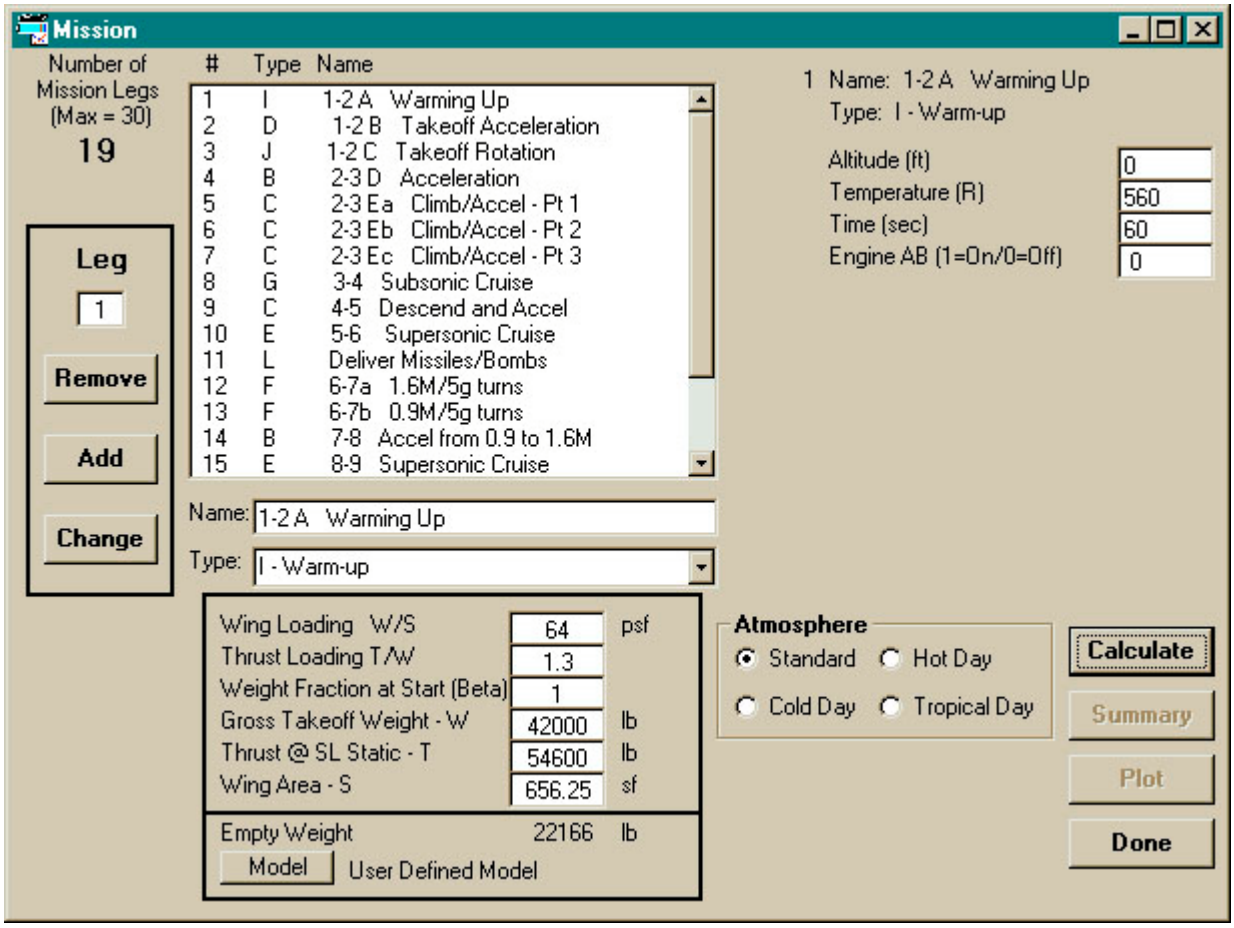


The layout of the plot (e.g., the color of the contours and location of the legend) can be changed by moving the mouse over the plot and pressing the right mouse button to display the plot properties (3D Chart Control Properties) window.



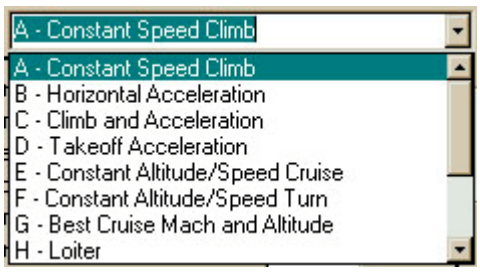
5. MISSION ANALYSIS

When either the **Mission Analysis** button or the corresponding pull-down item in the System Analysis menu is selected, the Mission Window is displayed as shown below.



The mission of interest can be constructed using the upper portion of this window. Double-clicking on an item in the upper left window causes the data for that mission leg to be displayed on the right side of the window for editing.

The mission analysis can model each of the fourteen (14) legs of the textbook. The type of mission leg is selected using the combo-box beside **Type** in the middle left of the window. Pressing the down arrow on the right edge of the box displays a list of mission leg types for user selection as shown below (if needed, the user can scroll to the desired leg).

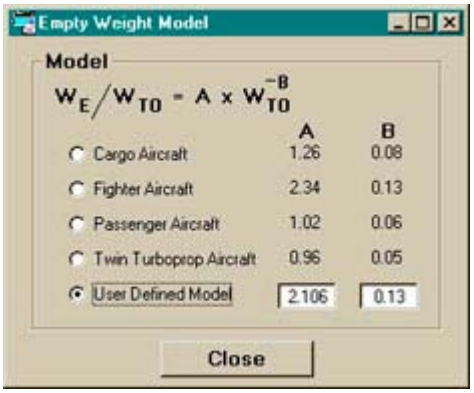

A - Constant Speed Climb
A - Constant Speed Climb
B - Horizontal Acceleration
C - Climb and Acceleration
D - Takeoff Acceleration
E - Constant Altitude/Speed Cruise
F - Constant Altitude/Speed Turn
G - Best Cruise Mach and Altitude
H - Loiter

I - Warm-up
J - Takeoff Rotation
K - Constant Energy Height Maneuver
L - Deliver Payload
M - Climb/Descend Angle

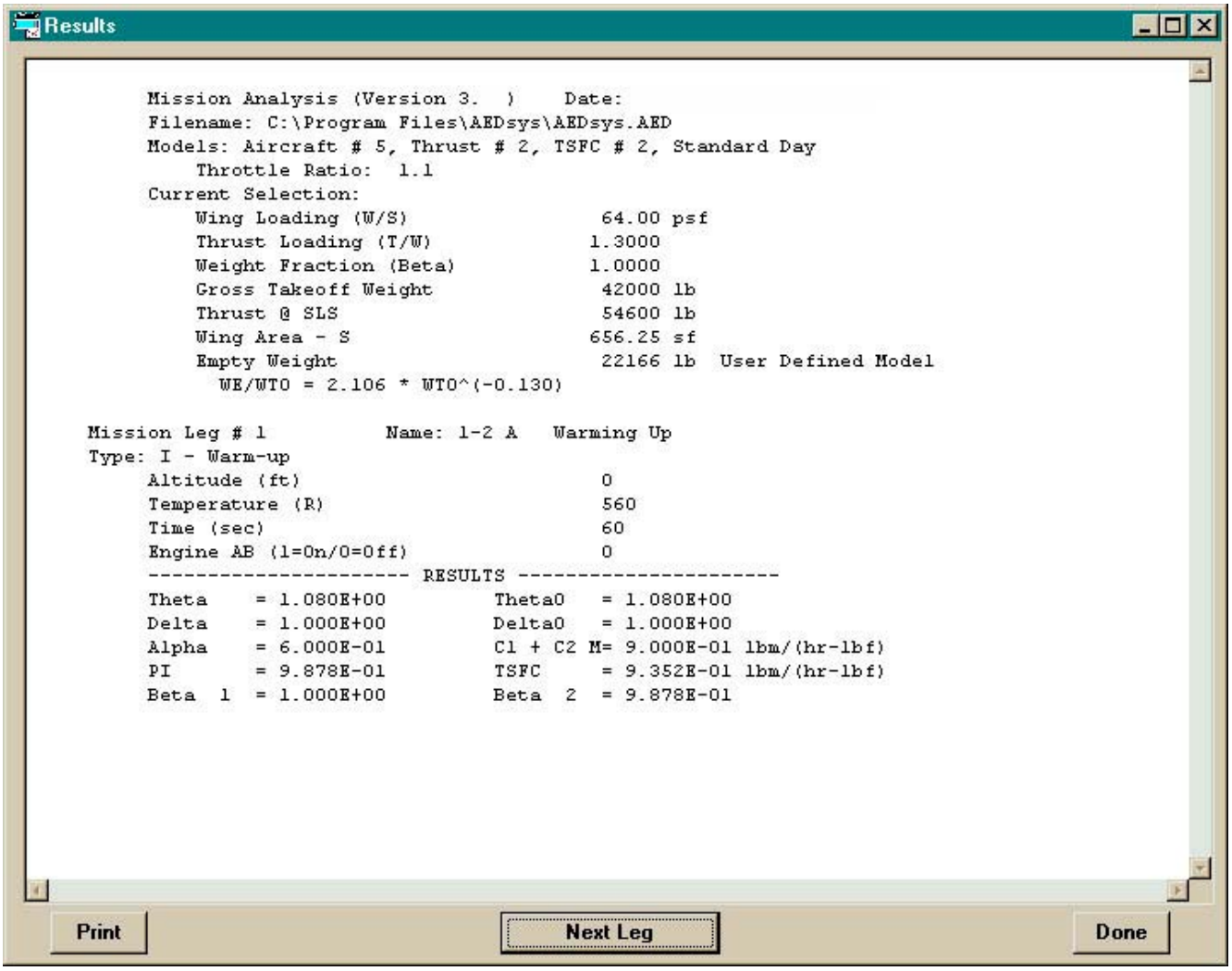
After a new mission leg type is selected, the user presses the **Change** button to change the current mission leg and the appropriate data list is shown on the right. Press the **Add** button to add a new leg at the current leg number. Press the **Remove** button to remove the current leg.

The **Atmosphere** radio buttons allow the user to specify the atmospheric model that is to be used for auto-update of the air temperature for new altitude data. For flight conditions corresponding to one of these atmospheric models, enter the altitude first and then enter the desired temperature.

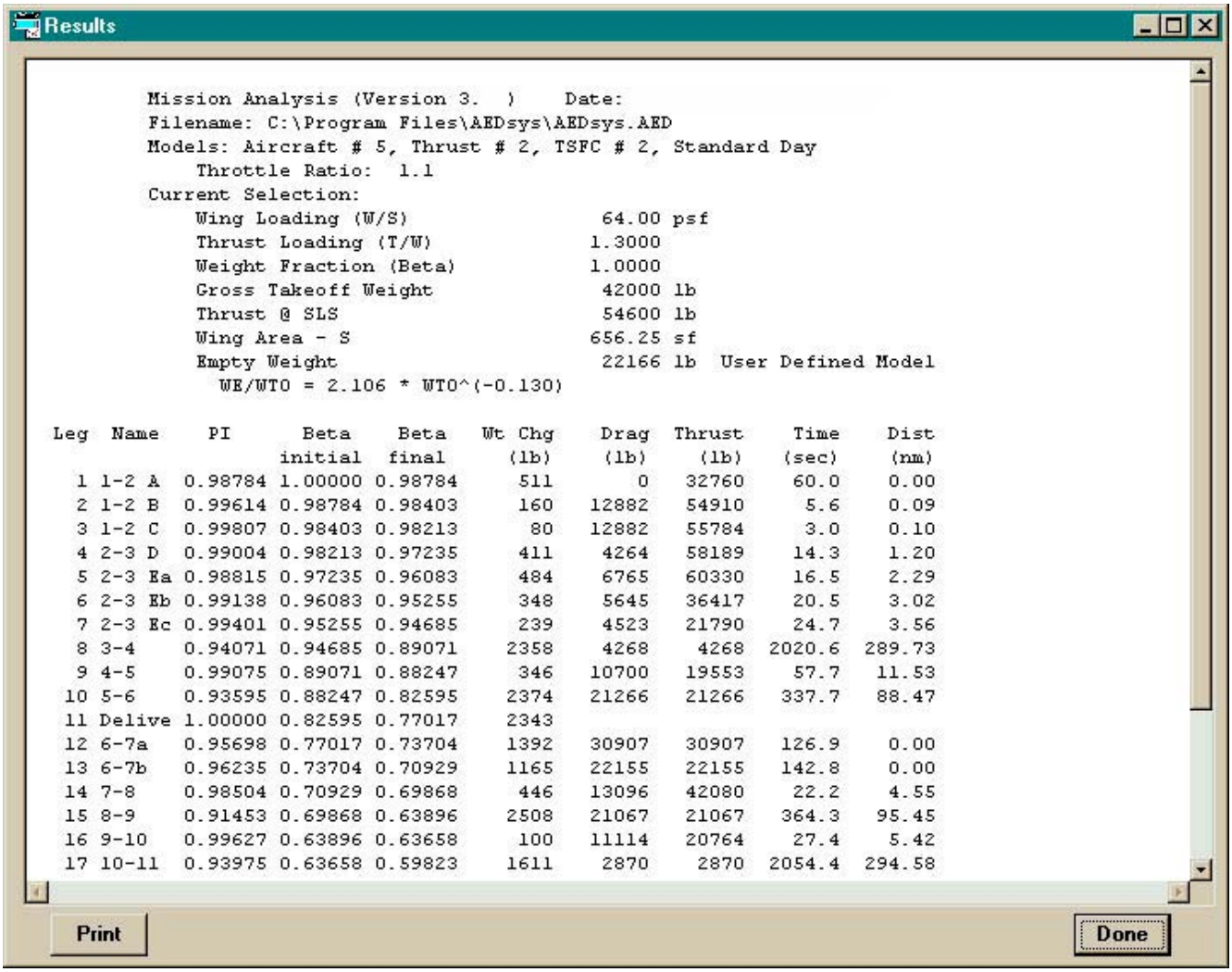
Pressing the **Model** button under Empty Weight displays the Empty Weight Model window that allows the user to select one of the models of Section 3.3.1 or enter their own model. This feature is useful when trying to fly mission and close on a empty weight that will meet the requirements of the RFP.



After the mission has been constructed by entering the mission legs and their data, the mission can be flown one leg at a time starting with the aircraft system design point thrust loading and wing loading, initial weight fraction (β), and gross takeoff weight (GTOW). Pressing the **Calculate** button at the bottom of the Mission window opens the Results window and displays the initial design data and results for the first mission leg as shown below.


Results
Mission Analysis (Version 3.) Date:
Filename: C:\Program Files\AEDsys\AEDsys.AED
Models: Aircraft # 5, Thrust # 2, TSFC # 2, Standard Day
Throttle Ratio: 1.1
Current Selection:
Wing Loading (W/S) 64.00 psf
Thrust Loading (T/W) 1.3000
Weight Fraction (Beta) 1.0000
Gross Takeoff Weight 42000 lb
Thrust @ SLS 54600 lb
Wing Area - S 656.25 sf
Empty Weight 22166 lb User Defined Model
WE/WTO = 2.106 * WTO^(-0.130)
Mission Leg # 1 Name: 1-2 A Warming Up
Type: I - Warm-up
Altitude (ft) 0
Temperature (R) 560
Time (sec) 60
Engine AB (1=On/0=Off) 0
---------- RESULTS ----------
Theta = 1.080E+00 Theta0 = 1.080E+00
Delta = 1.000E+00 Delta0 = 1.000E+00
Alpha = 6.000E-01 C1 + C2 M= 9.000E-01 lbm/(hr-lbf)
PI = 9.878E-01 TSFC = 9.352E-01 lbm/(hr-lbf)
Beta 1 = 1.000E+00 Beta 2 = 9.878E-01
Print
Next Leg
Done

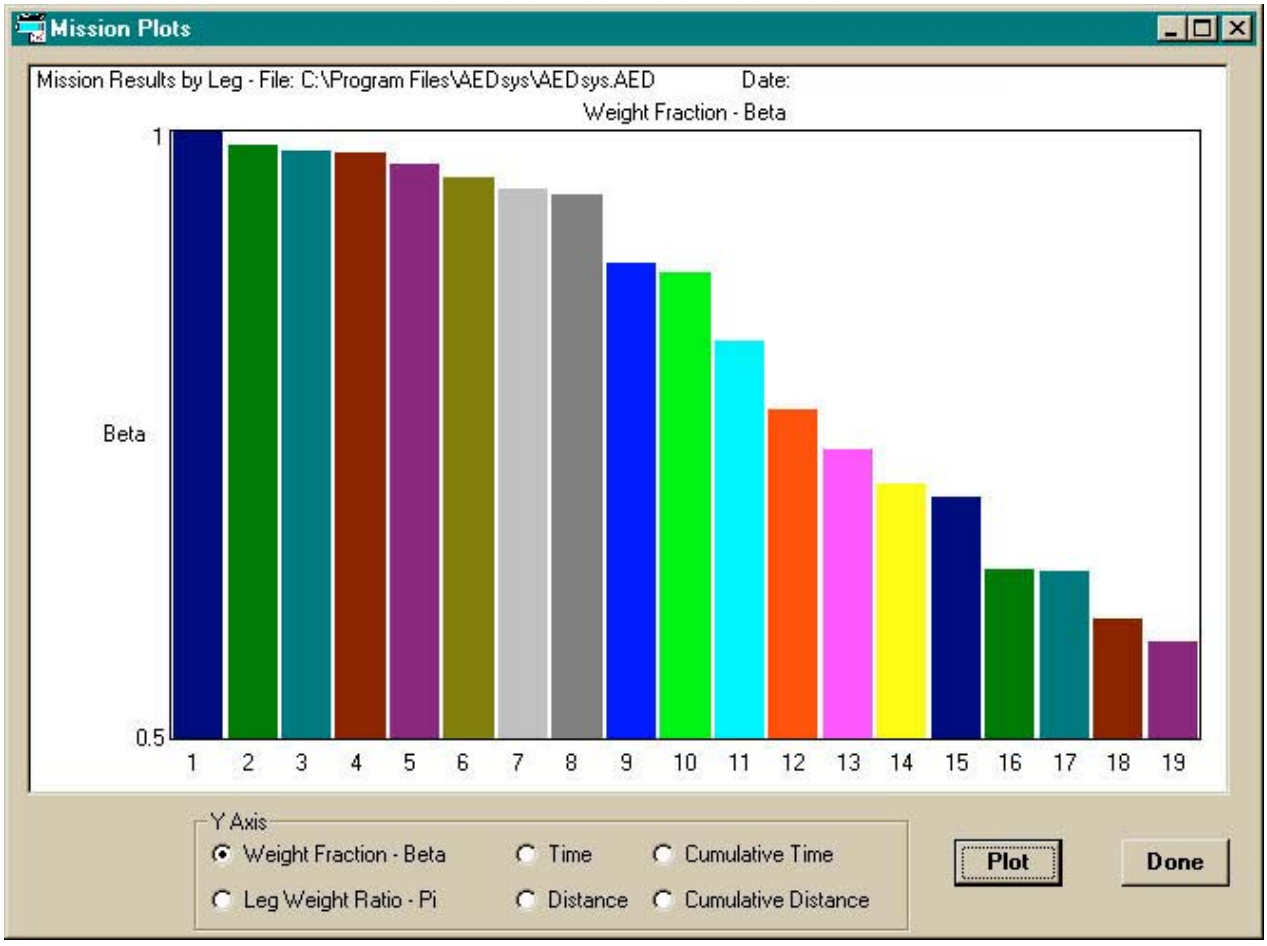
The **Summary** and **Plot** buttons on the Mission window become active after at least one mission leg is calculated. After calculation of basic engine thrust model and fuel consumption model of Chapters 2 and 3 (model 1-5), pressing the **Summary** button displays a single-page summary of the mission results as shown below. If the user constructs the mission such that the payload is removed at the end of the mission, the final weight of the aircraft can be compared to the predicted empty weight.




```
        Mission Analysis (Version 3.  )    Date:
        Filename: C:\Program Files\AEDsys\AEDsys.AED
        Models: Aircraft # 5, Thrust # 2, TSFC # 2, Standard Day
            Throttle Ratio:  1.1
        Current Selection:
            Wing Loading (W/S)                64.00 psf
            Thrust Loading (T/W)             1.3000
            Weight Fraction (Beta)           1.0000
            Gross Takeoff Weight              42000 lb
            Thrust @ SLS                      54600 lb
            Wing Area - S                    656.25 sf
            Empty Weight                      22166 lb  User Defined Model
              WE/WTO = 2.106 * WTO^(-0.130)

Leg  Name     PI       Beta     Beta    Wt Chg    Drag  Thrust     Time     Dist
                     initial   final     (lb)     (lb)    (lb)    (sec)     (nm)
  1 1-2 A  0.98784 1.00000 0.98784      511        0   32760     60.0     0.00
  2 1-2 B  0.99614 0.98784 0.98403      160    12882   54910      5.6     0.09
  3 1-2 C  0.99807 0.98403 0.98213       80    12882   55784      3.0     0.10
  4 2-3 D  0.99004 0.98213 0.97235      411     4264   58189     14.3     1.20
  5 2-3 Ea 0.98815 0.97235 0.96083      484     6765   60330     16.5     2.29
  6 2-3 Eb 0.99138 0.96083 0.95255      348     5645   36417     20.5     3.02
  7 2-3 Ec 0.99401 0.95255 0.94685      239     4523   21790     24.7     3.56
  8 3-4    0.94071 0.94685 0.89071     2358     4268    4268   2020.6   289.73
  9 4-5    0.99075 0.89071 0.88247      346    10700   19553     57.7    11.53
 10 5-6    0.93595 0.88247 0.82595     2374    21266   21266    337.7    88.47
 11 Delive 1.00000 0.82595 0.77017     2343
 12 6-7a   0.95698 0.77017 0.73704     1392    30907   30907    126.9     0.00
 13 6-7b   0.96235 0.73704 0.70929     1165    22155   22155    142.8     0.00
 14 7-8    0.98504 0.70929 0.69868      446    13096   42080     22.2     4.55
 15 8-9    0.91453 0.69868 0.63896     2508    21067   21067    364.3    95.45
 16 9-10   0.99627 0.63896 0.63658      100    11114   20764     27.4     5.42
 17 10-11  0.93975 0.63658 0.59823     1611     2870    2870   2054.4   294.58
```

Pressing the **Plot** button at the bottom of the Mission window opens the Mission Plots window. The user selects the plot at the bottom of this window and presses the **Plot** button to obtain a plot like that shown below with a bar chart based on the mission leg number.



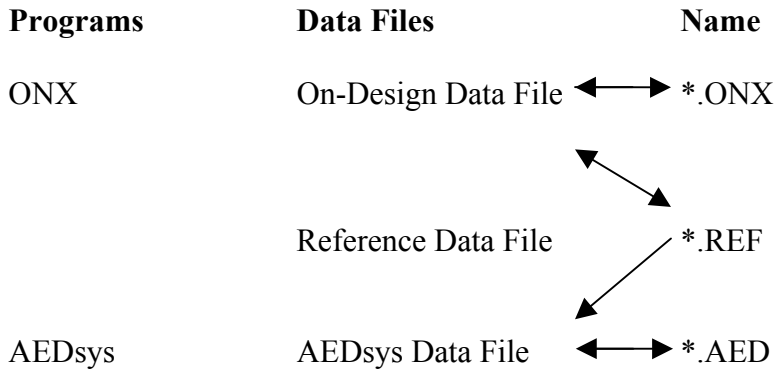
6. ENGINE CYCLE DESIGN PROGRAMS and DESIGN STEPS

ONX - Parametric Engine Analysis – determines the change in an engine's uninstalled performance with changes in the engine design parameters (a design parameter like compressor pressure ratio). Can calculate the performance of a reference engine (each design parameter set to one design value) and output a reference data file (*.REF).

AEDsys - Performs constraint analysis, contour plots, mission analysis, and engine test – can input reference data from ONX program and fly this engine through the mission; run engine performance calculations (variation in an engine's uninstalled performance with changes in engine flight conditions (altitude and Mach number) and engine throttle (T_{t4}); perform constraint analysis and generate contour plots. When an *.AED data file is saved with a reference engine, the reference data for that engine is saved inside the *.AED data file.

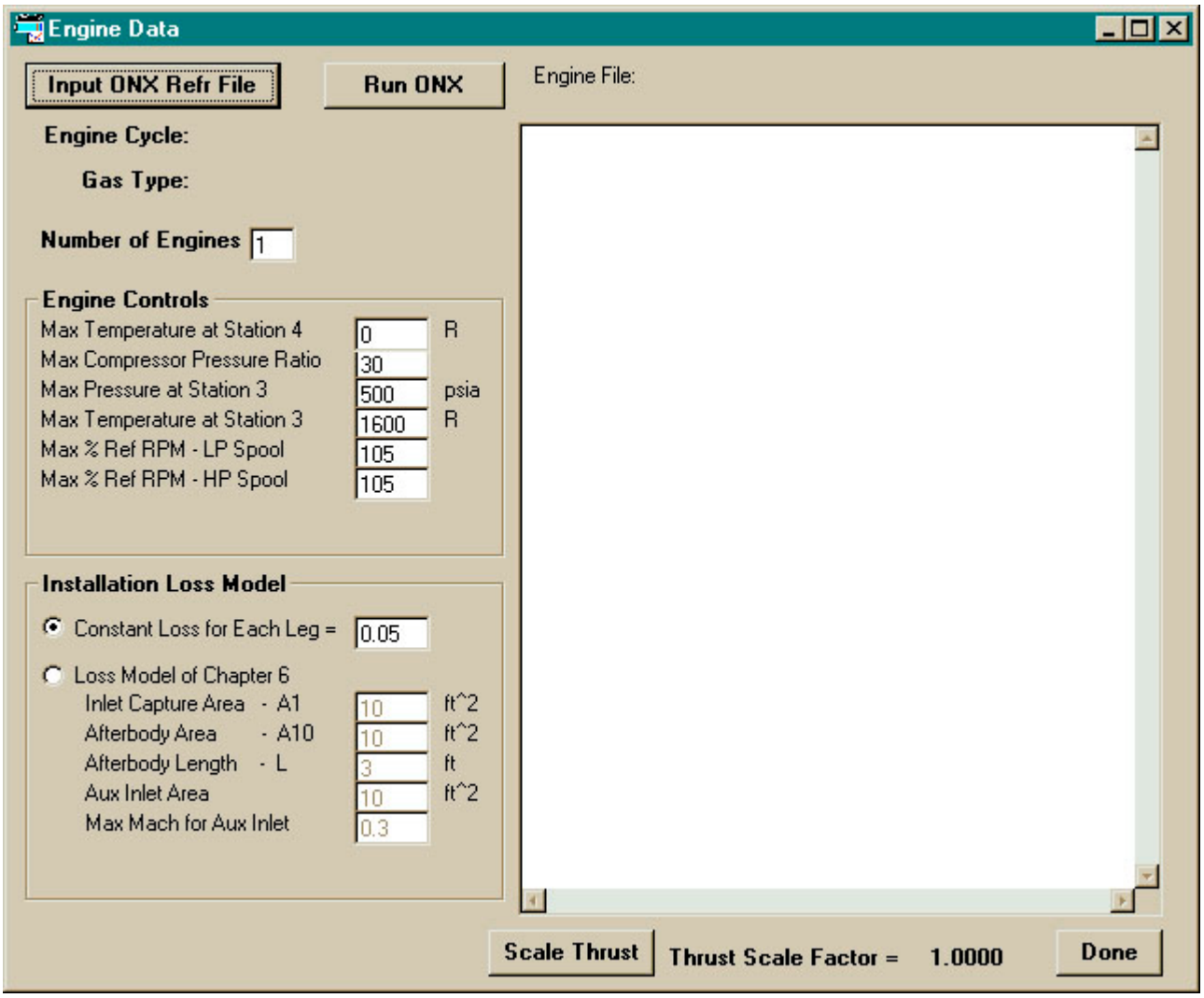
Basic Steps

1. Design an engine in ONX program at a single design point and save the Reference Engine Data file (*.REF)
2. Using the AEDsys program, select **Cycle Deck** under Engine pull-down menu or press the **Engine Data** button of AEDsys program and read in the ONX Reference Engine Data file (*.REF)
3. Input engine control values. Run Constraint analysis to determine the required thrust loading (T_{SL}/W_{TO}) for the selected wing loading (W_{TO}/S). Run Mission analysis and determine fuel used. If engine is too small for any flight condition, increase the system T_{SL}/W_{TO} as required and rerun the mission. The engine is automatically scaled (TSF) in accordance with T_{SL}/W_{TO} at the start of the mission analysis.
4. Repeat steps 1 through 3 for another engine design until desired results are reached.
5. Review second summary sheet of mission analysis and find largest required A_1 and A_{10}.
6. Select Chapter 6 Installation Model in Engine Data screen. Input design A_1, A_{10}, and nozzle length (L). Determine mission performance with this installation loss model.

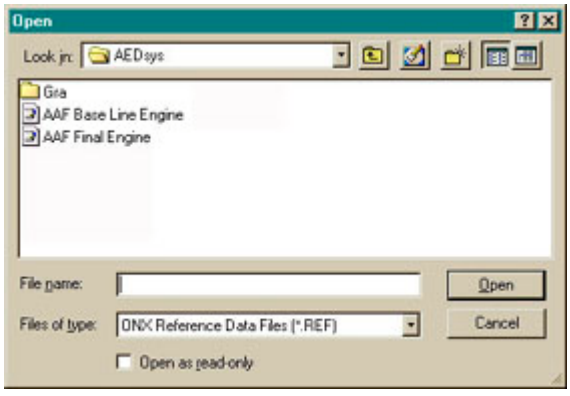


7. ENGINE CYCLE DECK MODEL – ENGINE DATA WINDOW

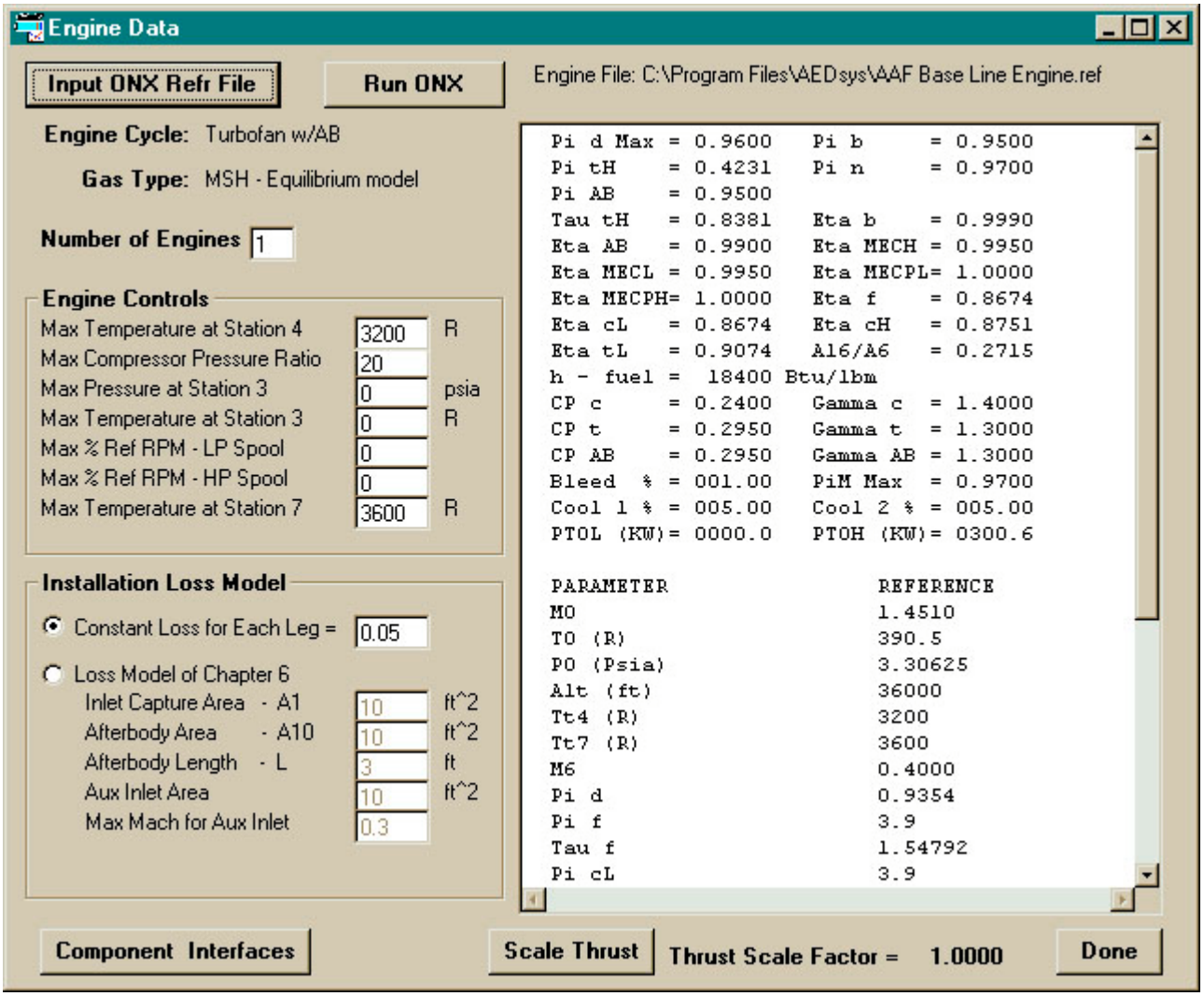
Selecting the **Cycle Deck** from the Engine pull down menu on the AEDsys main window opens the Engine Data window, shown below, and accesses the ONX program (press **Run ONX** button) and the input of engine reference data from the ONX program (press **Input ONX Refr File** button).


Engine Data
Input ONX Refr File
Run ONX
Engine File:
Engine Cycle:
Gas Type:
Number of Engines 1
Engine Controls
Max Temperature at Station 4 0 R
Max Compressor Pressure Ratio 30
Max Pressure at Station 3 500 psia
Max Temperature at Station 3 1600 R
Max % Ref RPM - LP Spool 105
Max % Ref RPM - HP Spool 105
Installation Loss Model
Constant Loss for Each Leg = 0.05
Loss Model of Chapter 6
Inlet Capture Area - A1 10 ft^2
Afterbody Area - A10 10 ft^2
Afterbody Length - L 3 ft
Aux Inlet Area 10 ft^2
Max Mach for Aux Inlet 0.3
Scale Thrust
Thrust Scale Factor = 1.0000
Done

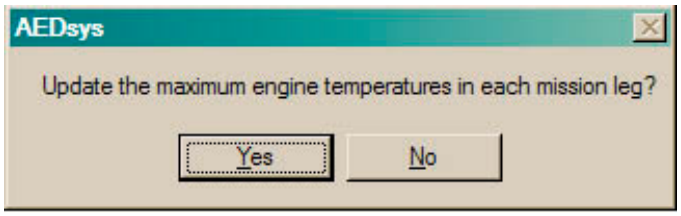
Pressing the **Input ONX Refr File** button opens a dialog window like that shown below to input an engine reference data file created by the ONX program.



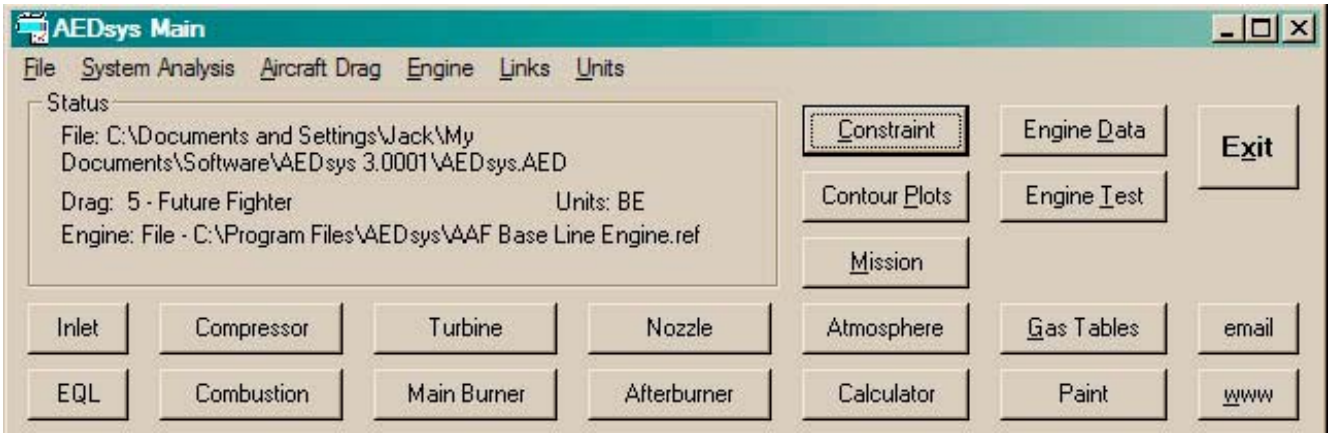
Selecting the **AAF Base Line Engine** reference data file in the Open window results in data being read into the Engine Data window and displayed as shown below. Note that the initial control limits for the **Max Temperature at Station 4**, **Max Compressor Pressure Ratio,** and **Max Temperature at Station 7** are the design point values. No control limits (zero values) are initially set for the other control limits.


Engine Data
Input ONX Refr File
Run ONX
Engine File: C:\Program Files\AEDsys\AAF Base Line Engine.ref
Engine Cycle: Turbofan w/AB
Gas Type: MSH - Equilibrium model
Number of Engines 1
Engine Controls
Max Temperature at Station 4 3200 R
Max Compressor Pressure Ratio 20
Max Pressure at Station 3 0 psia
Max Temperature at Station 3 0 R
Max % Ref RPM - LP Spool 0
Max % Ref RPM - HP Spool 0
Max Temperature at Station 7 3600 R
Installation Loss Model
Constant Loss for Each Leg = 0.05
Loss Model of Chapter 6
Inlet Capture Area - A1 10 ft^2
Afterbody Area - A10 10 ft^2
Afterbody Length - L 3 ft
Aux Inlet Area 10 ft^2
Max Mach for Aux Inlet 0.3
Pi d Max = 0.9600 Pi b = 0.9500
Pi tH = 0.4231 Pi n = 0.9700
Pi AB = 0.9500
Tau tH = 0.8381 Eta b = 0.9990
Eta AB = 0.9900 Eta MECH = 0.9950
Eta MECL = 0.9950 Eta MECPL= 1.0000
Eta MECPH= 1.0000 Eta f = 0.8674
Eta cL = 0.8674 Eta cH = 0.8751
Eta tL = 0.9074 A16/A6 = 0.2715
h - fuel = 18400 Btu/lbm
CP c = 0.2400 Gamma c = 1.4000
CP t = 0.2950 Gamma t = 1.3000
CP AB = 0.2950 Gamma AB = 1.3000
Bleed % = 001.00 PiM Max = 0.9700
Cool 1 % = 005.00 Cool 2 % = 005.00
PTOL (KW)= 0000.0 PTOH (KW)= 0300.6
PARAMETER REFERENCE
M0 1.4510
T0 (R) 390.5
P0 (Psia) 3.30625
Alt (ft) 36000
Tt4 (R) 3200
Tt7 (R) 3600
M6 0.4000
Pi d 0.9354
Pi f 3.9
Tau f 1.54792
Pi cL 3.9
Component Interfaces
Scale Thrust
Thrust Scale Factor = 1.0000
Done

As shown below, the user is asked if they would like to update the maximum engine temperature(s) $\{T_{t4}$ and $T_{t7}\}$ in each mission leg with the value(s) contained in the engine reference file. If either the maximum temperature at station 4 or the maximum temperature at station 7 is changed in the above window, the user is asked if they would like this new value to be used in all mission legs.



After an engine reference data file has been loaded into the AEDsys program, this engine's reference data is used in the engine performance model for all analyses and the **Engine Data** button and **Engine Test** button are added to the AEDsys Main window as shown below to facilitate navigation.



The Engine Data window is also the window for entering the **Number of Engines, Engine Control** limits, and the **Installation Loss Model**. In addition, pressing the **Scale Thrust** button will scale the engine thrust (calculate the Thrust Scale Factor) so that the specified number of engines produce the thrust specified on the Mission Analysis window.

Pressing the **Component Interface** button opens the Component Interfaces window. Press the **Calculate** button to display the component flow properties based on the user input Mach number data (initial estimates) at the top of the window and the Thrust Scale Factor as shown below. The resulting annular flow areas are used in Engine Station Test Results calculations within the Engine Test window.

Component Interfaces

Mach @ 1 0.8 Mach @ 2 0.5 Mach @ 3.2 0.08 Mach @ 5 0.6 Mach @ 7 0.5

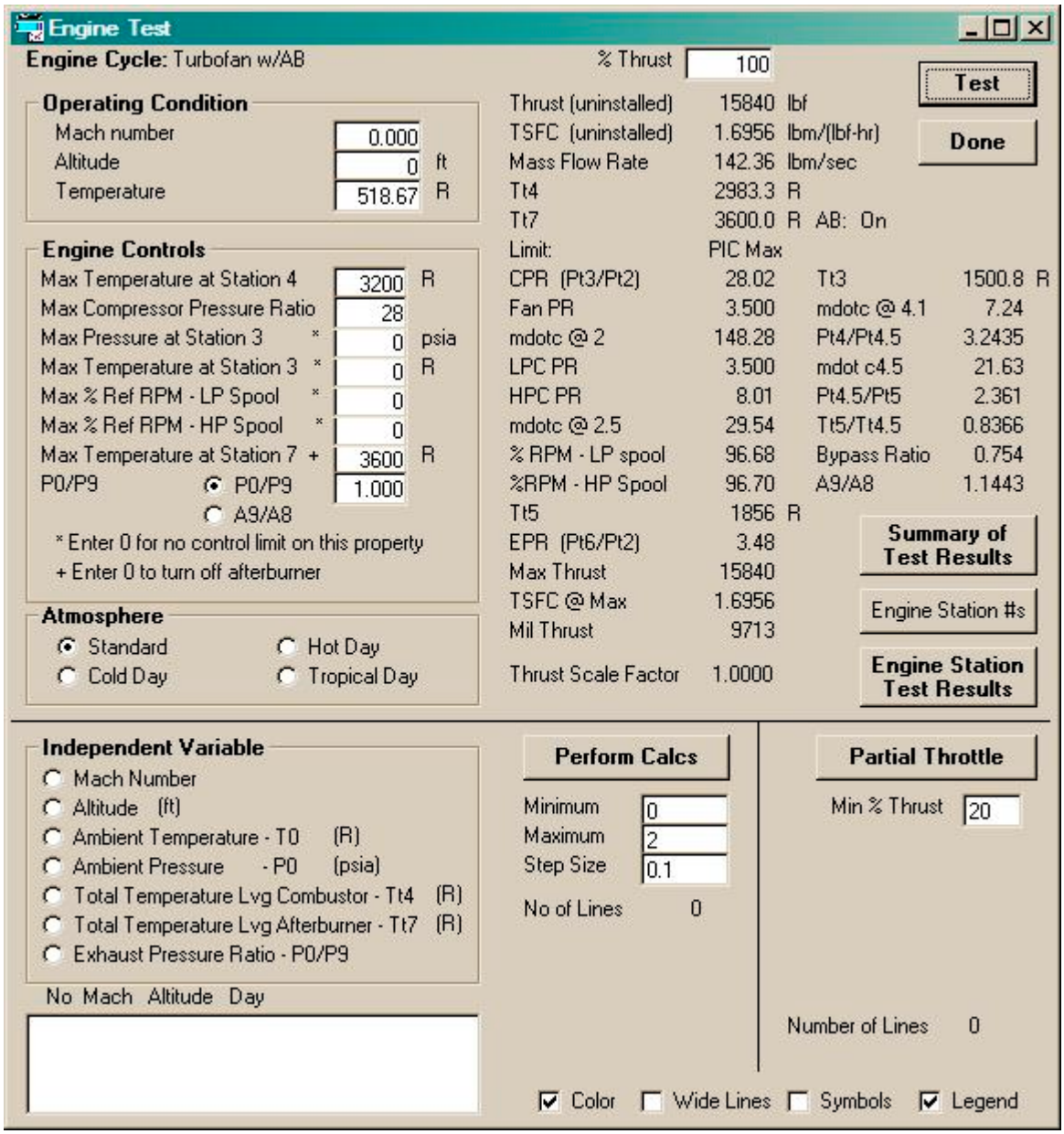
Design Interface Quantities (Version 3.) Date:
Filename: C:\Program Files\AEDsys\AEDsys.AED
Engine File Name: C:\Program Files\AEDsys\AAF Base Line Engine.ref
Thrust Scale Factor = 1.0000

Station	m dot (lbm/s)	gamma	Pt (psia)	Tt (R)	P (psia)	T (R)	Mach	Velocity (ft/s)	Area (ft^2)	Area* (ft^2)	I (lbf)
0	200.00	1.4000	11.311	554.93	3.306	390.50	1.4510	1405.54	6.227	5.440	11702.8
1	200.00	1.4000	11.021	554.93	7.230	491.96	0.8000	869.80	5.797	5.583	11442.8
2	200.00	1.4000	10.581	554.93	8.920	528.51	0.5000	563.46	7.792	5.816	13511.7
13	200.00	1.4000	41.264	858.99	36.991	832.57	0.3984	563.46	2.960	1.855	19270.4
core	138.06	1.4000	41.264	858.99	36.991	832.57	0.3984	563.46	2.043	1.281	13302.0
bypass	61.94	1.4000	41.264	858.99	36.991	832.57	0.3984	563.46	0.917	0.575	5968.3
2.5	138.06	1.4000	41.264	858.99	36.991	832.57	0.3984	563.46	2.043	1.281	13302.0
3.0	138.06	1.4000	211.612	1443.36	198.363	1416.94	0.3054	563.46	0.648	0.324	20941.1
3.1	122.87	1.4000	211.612	1443.36	198.363	1416.94	0.3054	563.46	0.577	0.288	18637.6
3.2	122.87	1.4000	209.496	1443.36	208.560	1441.52	0.0800	148.89	2.113	0.291	64037.1
MB fuel	3.7710										
4	126.64	1.3000	201.032	3200.00	109.708	2782.61	1.0000	2483.05	0.476	0.476	17291.8
4.1	133.54	1.3000		3095.29							
4.4	133.54	1.3000	85.060	2594.07							
4.5	140.45	1.3000	85.060	2524.29	46.419	2195.03	1.0000	2205.36	1.108	1.108	17032.2
5	140.45	1.3000	41.090	2170.26	32.716	2059.07	0.6000	1281.58	2.537	2.126	17548.3
6	140.45	1.3000	41.090	2170.26	37.077	2119.39	0.4000	866.81	3.407	2.126	21975.4
16	61.94	1.4000	41.264	858.99	37.077	833.13	0.3940	557.49	0.925	0.575	6012.8
6A	202.39	1.3250	39.597	1824.00	35.310	1773.45	0.4188	839.14	4.466	2.899	27988.1
AB fuel	6.6582										
7	209.05	1.3000	37.617	3600.00	32.070	3469.88	0.5000	1386.39	6.002	4.453	36724.9

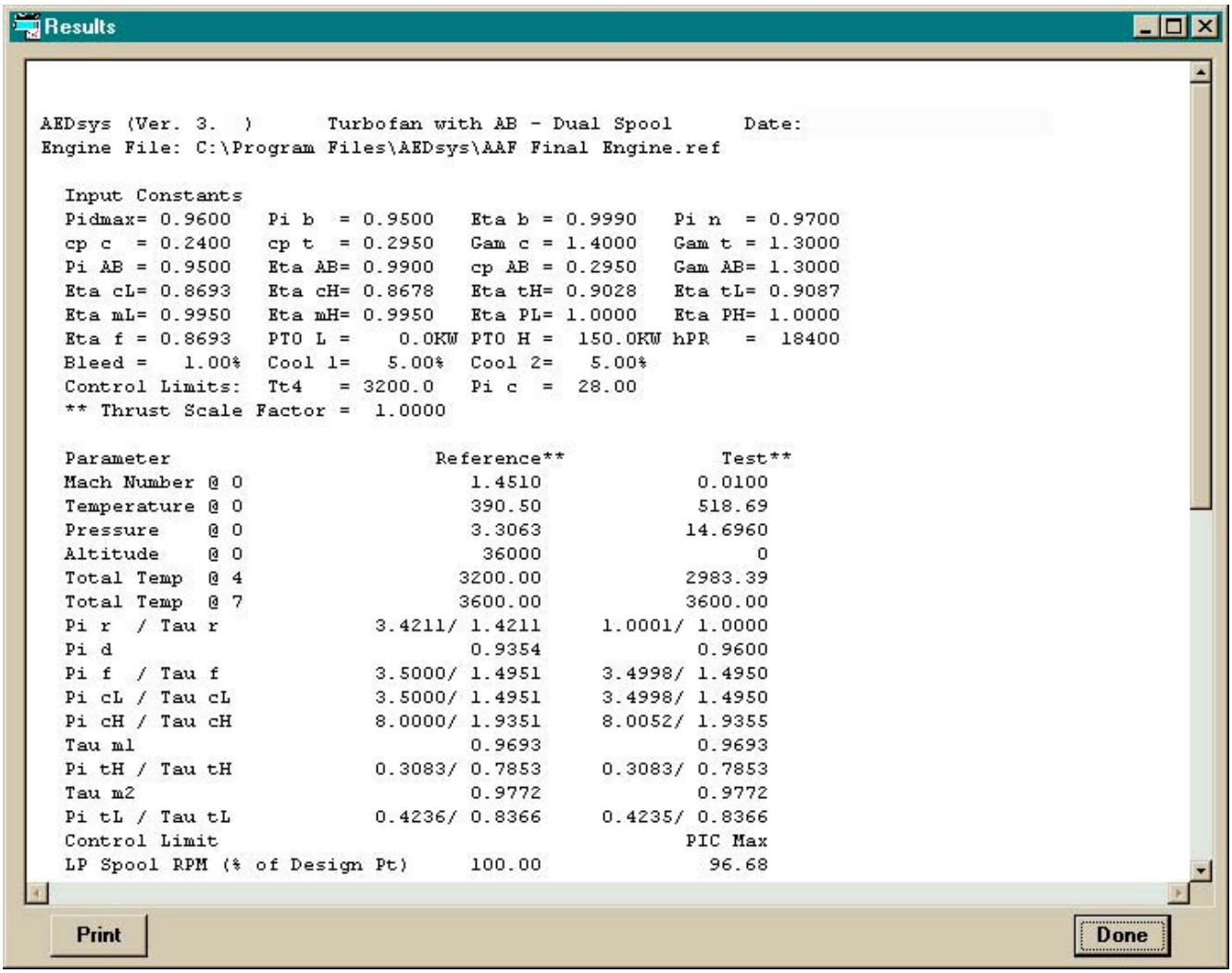
Print Calculate Done

8. ENGINE CYCLE DECK MODEL – ENGINE TEST WINDOW

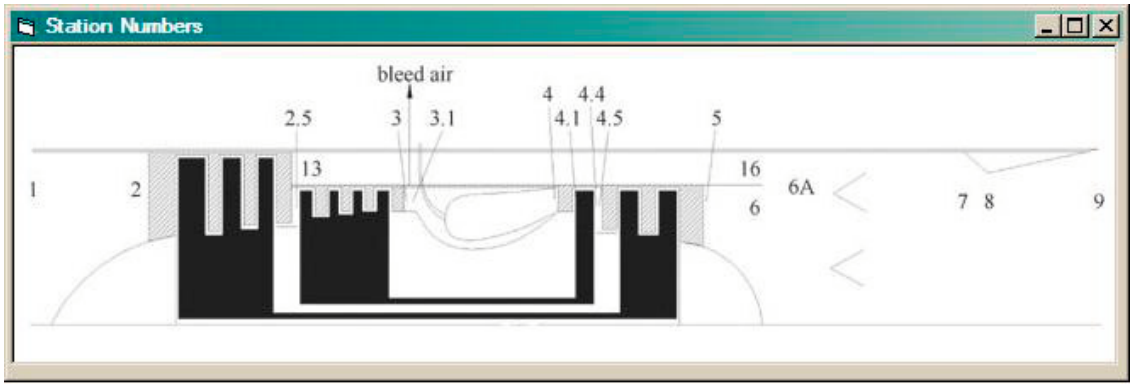
Pressing the **Engine Test** button on the AEDsys main window opens the Engine Test window, shown below, and performance analysis of the reference engine. Pressing the **Test** button causes the performance analysis software to calculate the engine performance at the percent thrust set in the % Thrust data field and update results on the right side of the Engine Test window.



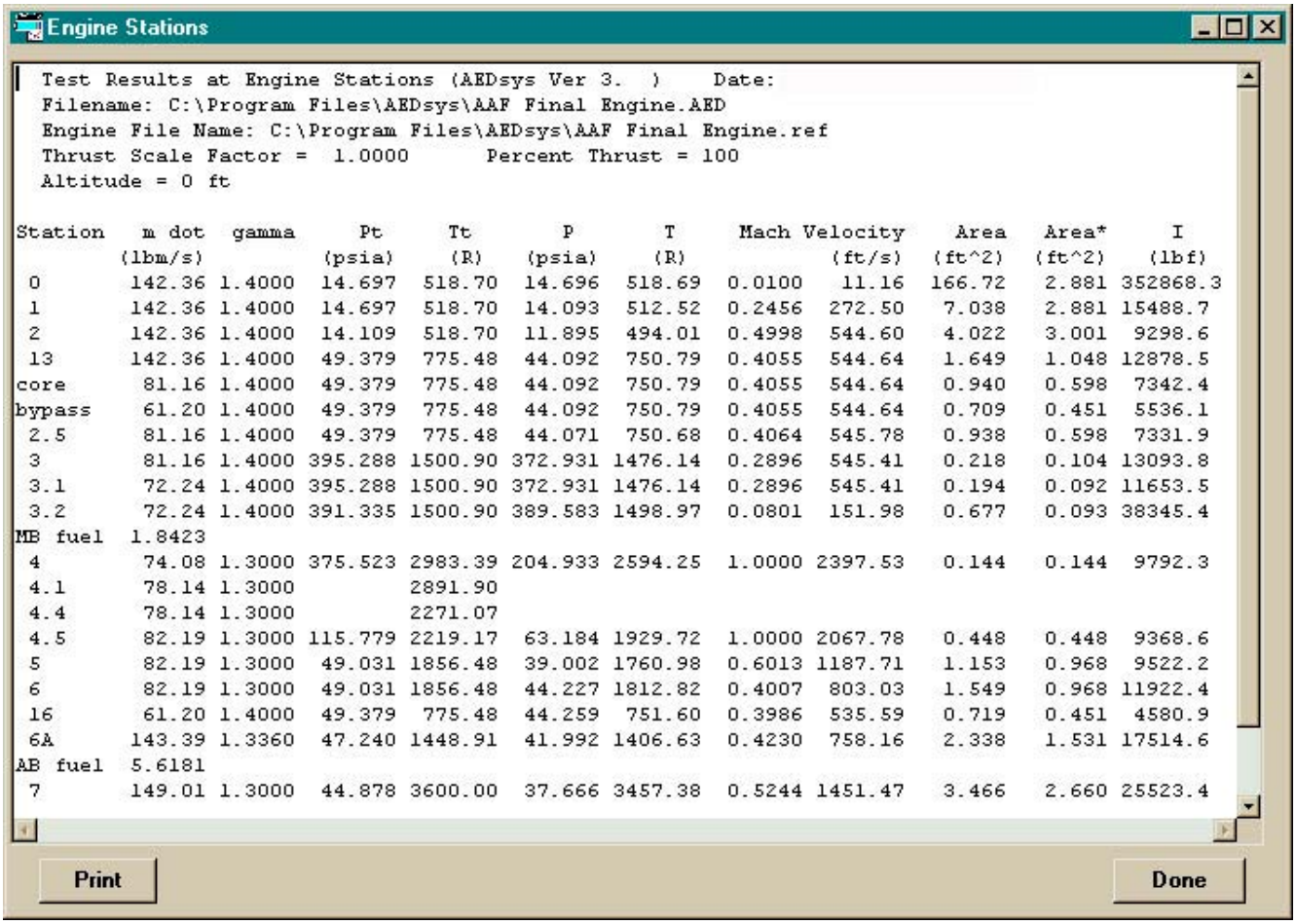
After performing a test, press the **Summary of Test Results** button in the Engine Test window to open the Results window and display a comparison of engine performance at the reference and test points as shown below.

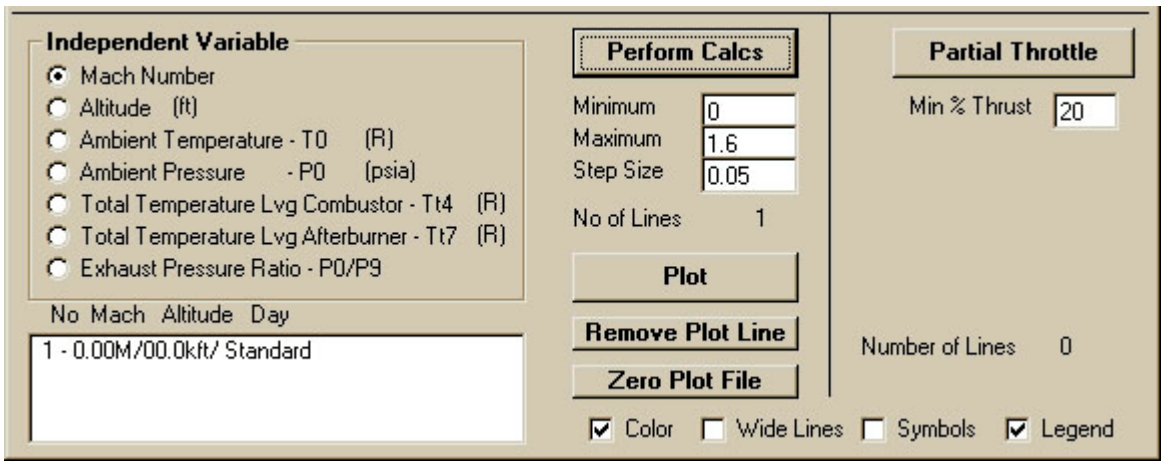

Results
AEDsys (Ver. 3.) Turbofan with AB - Dual Spool Date:
Engine File: C:\Program Files\AEDsys\AAF Final Engine.ref
Input Constants
Pidmax= 0.9600 Pi b = 0.9500 Eta b = 0.9990 Pi n = 0.9700
cp c = 0.2400 cp t = 0.2950 Gam c = 1.4000 Gam t = 1.3000
Pi AB = 0.9500 Eta AB= 0.9900 cp AB = 0.2950 Gam AB= 1.3000
Eta cL= 0.8693 Eta cH= 0.8678 Eta tH= 0.9028 Eta tL= 0.9087
Eta mL= 0.9950 Eta mH= 0.9950 Eta PL= 1.0000 Eta PH= 1.0000
Eta f = 0.8693 PTO L = 0.0KW PTO H = 150.0KW hPR = 18400
Bleed = 1.00% Cool 1= 5.00% Cool 2= 5.00%
Control Limits: Tt4 = 3200.0 Pi c = 28.00
** Thrust Scale Factor = 1.0000
Parameter Reference** Test**
Mach Number @ 0 1.4510 0.0100
Temperature @ 0 390.50 518.69
Pressure @ 0 3.3063 14.6960
Altitude @ 0 36000 0
Total Temp @ 4 3200.00 2983.39
Total Temp @ 7 3600.00 3600.00
Pi r / Tau r 3.4211/ 1.4211 1.0001/ 1.0000
Pi d 0.9354 0.9600
Pi f / Tau f 3.5000/ 1.4951 3.4998/ 1.4950
Pi cL / Tau cL 3.5000/ 1.4951 3.4998/ 1.4950
Pi cH / Tau cH 8.0000/ 1.9351 8.0052/ 1.9355
Tau m1 0.9693 0.9693
Pi tH / Tau tH 0.3083/ 0.7853 0.3083/ 0.7853
Tau m2 0.9772 0.9772
Pi tL / Tau tL 0.4236/ 0.8366 0.4235/ 0.8366
Control Limit PIC Max
LP Spool RPM (% of Design Pt) 100.00 96.68
Print
Done

Press the **Engine Station #** button on the Engine Test window to display a sketch of the engine showing engine station numbers as shown below.



After performing a test, press the **Engine Station Test Results** button in the Engine Test window to open the Engine Station window and display the component interface flow properties as shown below. These are based on the annular flow areas calculated using the **Component Interface** button within the Engine Data window. If the **Component Interface** button has not been pressed and the annular flow areas calculated, then only the mass flow rates, ratio of specific heats, and total properties are shown for each engine station.





The engine performance can be calculated at full throttle (military and maximum power) and plotted using the lower left of the Engine Test window as shown above. After the **Perform Calcs** button is pressed, the Results window is opened and the predicted engine performance displayed as shown below. The program saves the variation of the engine performance with the independent variable for later plotting. The status of the saved plot data is updated in the Engine Test window. Up to 21 plot lines can be plotted.

Results

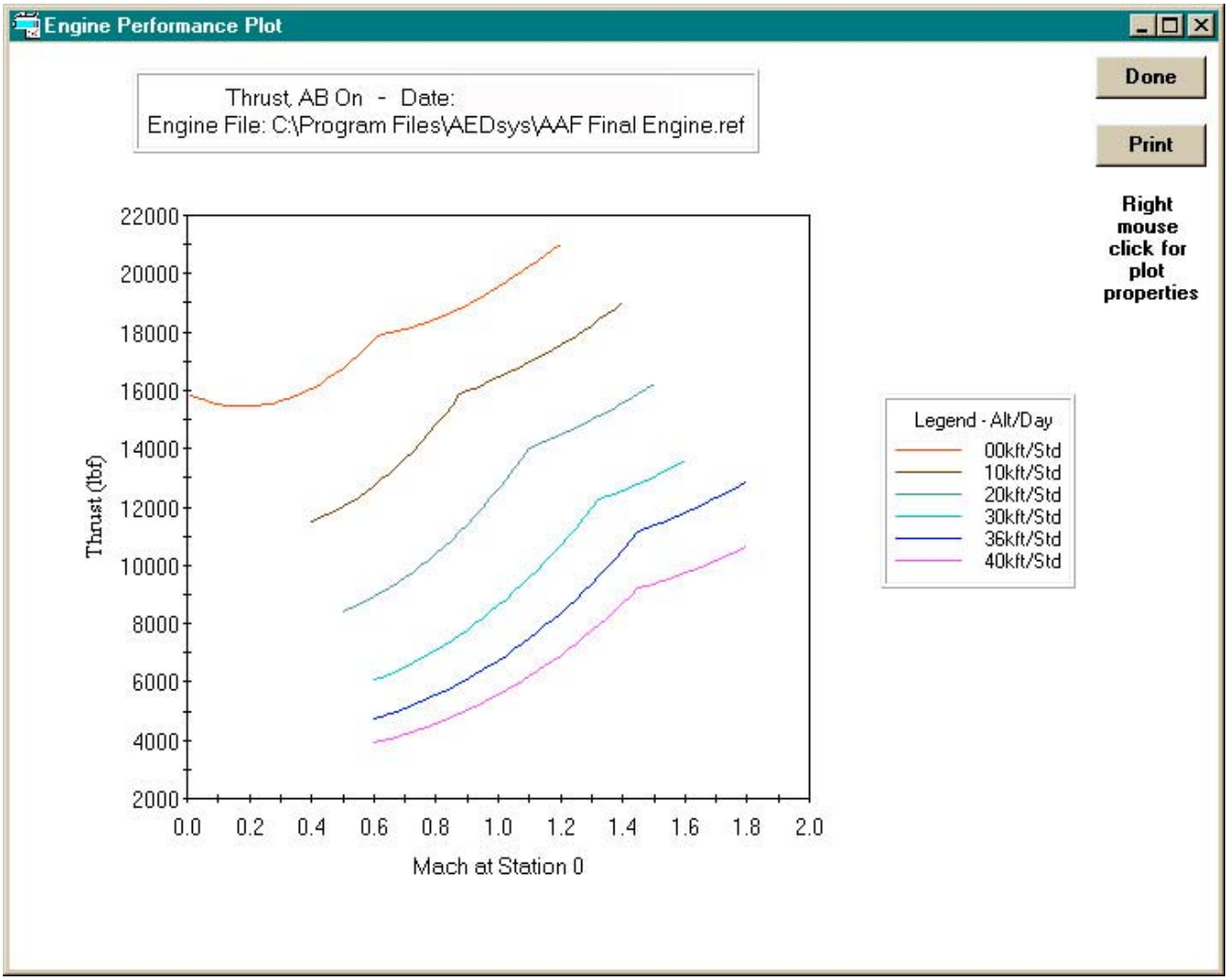
```
AEDsys (Version 3.  )    Date:
Engine File: C:\Program Files\AEDsys\AAF Final Engine.ref
Performance Calcs @ Mach =   0.00, Altitude =      0 ft, T0 = 518.67 R, Standard Day
    **** Mixed Flow Turbofan Engine *****
     M0 Thrust     S      mdot     pic     pif  Alpha Pt9/P9   PitL     Tt4 A0|A0*  Area9  Limit
   0.01  15840 1.6956   142.36   28.02   3.500  0.754 2.9621 0.4235 2983.3  2.882  3.044 PIC Max
   0.05  15686 1.7145   142.56   28.02   3.500  0.754 2.9669 0.4235 2984.6  2.881  3.045 PIC Max
   0.10  15540 1.7381   143.19   28.01   3.499  0.754 2.9820 0.4235 2988.7  2.881  3.049 PIC Max
   0.15  15460 1.7594   144.25   28.01   3.498  0.754 3.0076 0.4235 2995.7  2.881  3.055 PIC Max
   0.20  15447 1.7785   145.76   28.00   3.498  0.754 3.0441 0.4235 3005.7  2.881  3.064 PIC Max
   0.25  15499 1.7954   147.72   28.00   3.498  0.754 3.0915 0.4234 3018.6  2.881  3.075 PIC Max
   0.30  15617 1.8098   150.15   28.00   3.497  0.754 3.1504 0.4234 3034.4  2.881  3.090 PIC Max
   0.35  15799 1.8220   153.06   28.00   3.497  0.754 3.2209 0.4234 3053.1  2.881  3.107 PIC Max
   0.40  16047 1.8318   156.45   28.00   3.496  0.754 3.3041 0.4234 3074.8  2.881  3.128 PIC Max
   0.45  16376 1.8388   160.45   28.03   3.498  0.753 3.4029 0.4233 3100.5  2.883  3.152 PIC Max
   0.50  16752 1.8448   164.86   28.01   3.497  0.753 3.5111 0.4233 3127.4  2.883  3.181 PIC Max
   0.55  17198 1.8486   169.84   28.00   3.495  0.753 3.6342 0.4232 3157.4  2.883  3.213 PIC Max
   0.60  17718 1.8507   175.43   28.00   3.494  0.753 3.7727 0.4232 3190.5  2.883  3.250 PIC Max
   0.65  17950 1.8634   179.26   27.40   3.437  0.760 3.8587 0.4244 3200.0  2.845  3.280 Tt4 Max
   0.70  18083 1.8796   182.53   26.56   3.357  0.771 3.9274 0.4262 3200.0  2.791  3.307 Tt4 Max
   0.75  18247 1.8950   186.10   25.71   3.276  0.782 4.0026 0.4282 3200.0  2.736  3.338 Tt4 Max
   0.80  18443 1.9096   190.00   24.84   3.193  0.794 4.0845 0.4303 3200.0  2.680  3.371 Tt4 Max
   0.85  18671 1.9234   194.24   23.97   3.109  0.806 4.1737 0.4325 3200.0  2.623  3.406 Tt4 Max
   0.90  18933 1.9365   198.83   23.09   3.025  0.820 4.2704 0.4349 3200.0  2.565  3.445 Tt4 Max
   0.95  19230 1.9487   203.79   22.22   2.941  0.834 4.3751 0.4375 3200.0  2.508  3.487 Tt4 Max
   1.00  19562 1.9601   209.15   21.36   2.857  0.849 4.4882 0.4401 3200.0  2.450  3.531 Tt4 Max
   1.05  19895 1.9717   214.64   20.51   2.775  0.865 4.6042 0.4430 3200.0  2.395  3.577 Tt4 Max
   1.10  20244 1.9831   220.40   19.67   2.694  0.882 4.7259 0.4459 3200.0  2.347  3.625 Tt4 Max
   1.15  20620 1.9940   226.51   18.85   2.614  0.900 4.8551 0.4490 3200.0  2.307  3.676 Tt4 Max
   1.20  21025 2.0043   233.01   18.06   2.537  0.918 4.9927 0.4522 3200.0  2.275  3.729 Tt4 Max
```

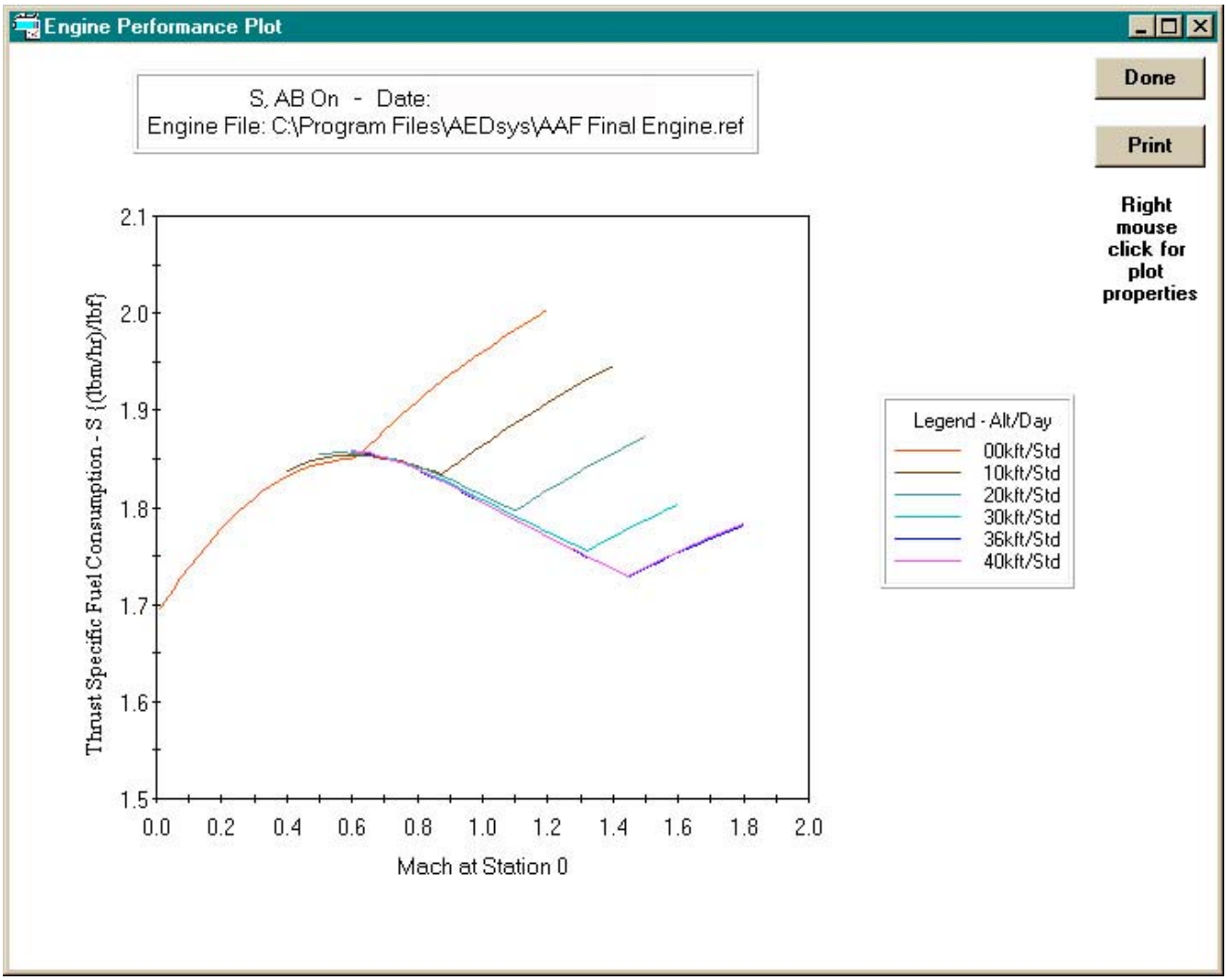
Print Done

As an example of a performance plot, the performance of the AAF Final Engine is calculated at maximum power over the range of Mach numbers listed for each altitude listed below for a standard day atmosphere.

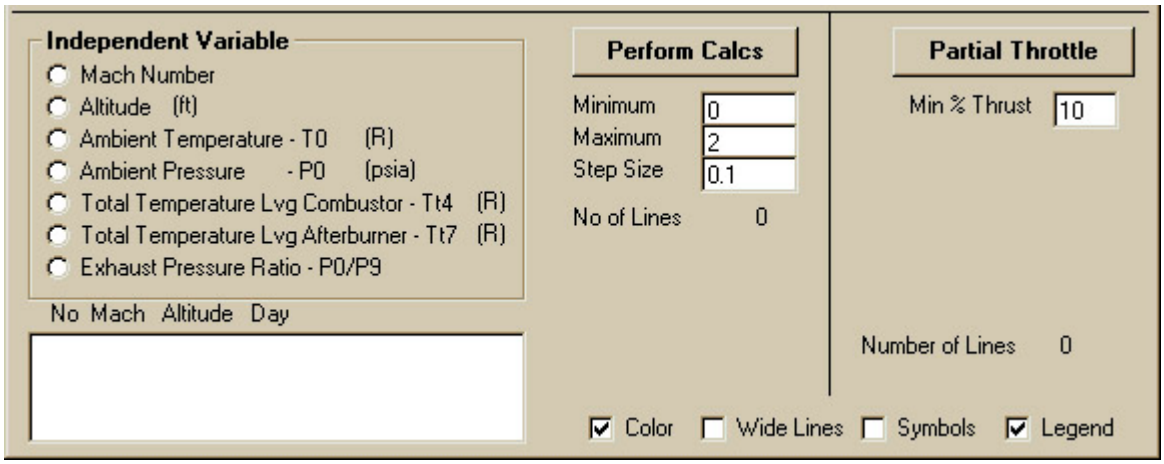
Altitude (kft)	Min Mach	Max Mach
0	0	1.2
10	0.4	1.4
20	0.5	1.5
30	0.6	1.6
36	0.6	1.8
40	0.6	1.8

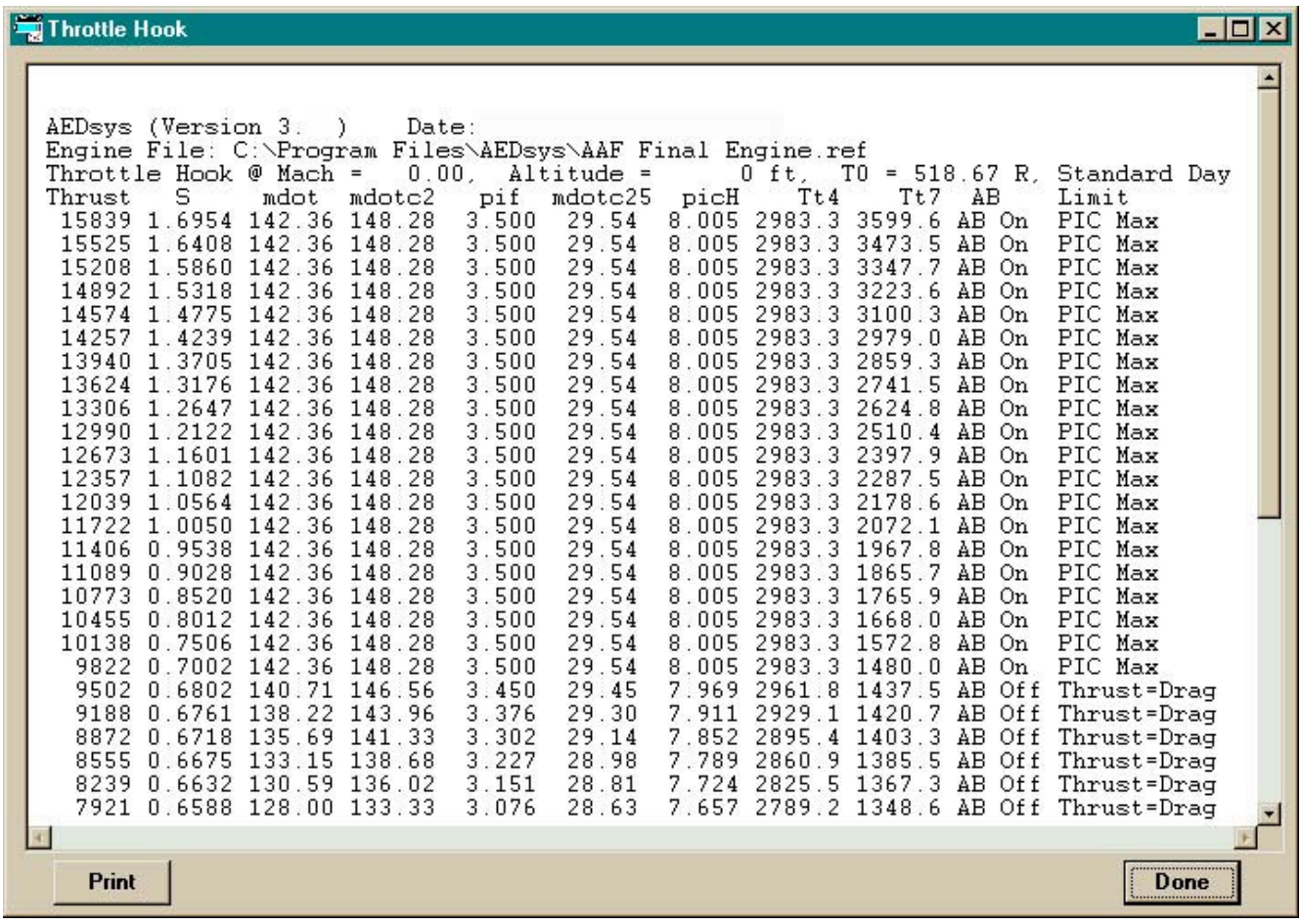
Once these calculations were done, the uninstalled thrust was plotted and is shown below. The uninstalled thrust specific fuel consumption (S) is shown on the next page.



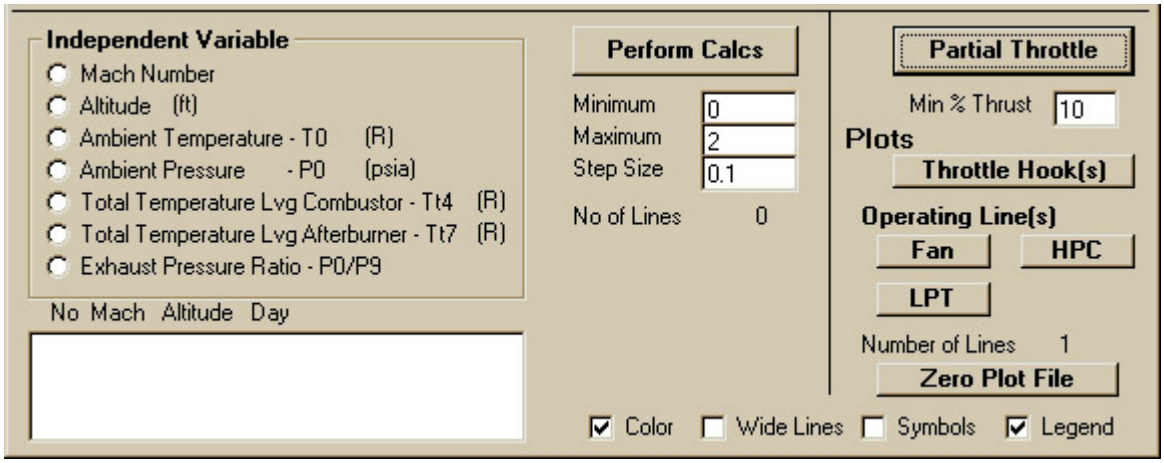


Similarly, the partial throttle performance of an engine can be calculated and plotted using the lower right of the Engine Test window (shown below). Press the **Partial Throttle** button to calculate the uninstalled performance of an engine from 100% down to the minimum thrust entered in the Min % Thrust data field (minimum value is 10%). The results are displayed in a Throttle Hook results window as shown on the next page.

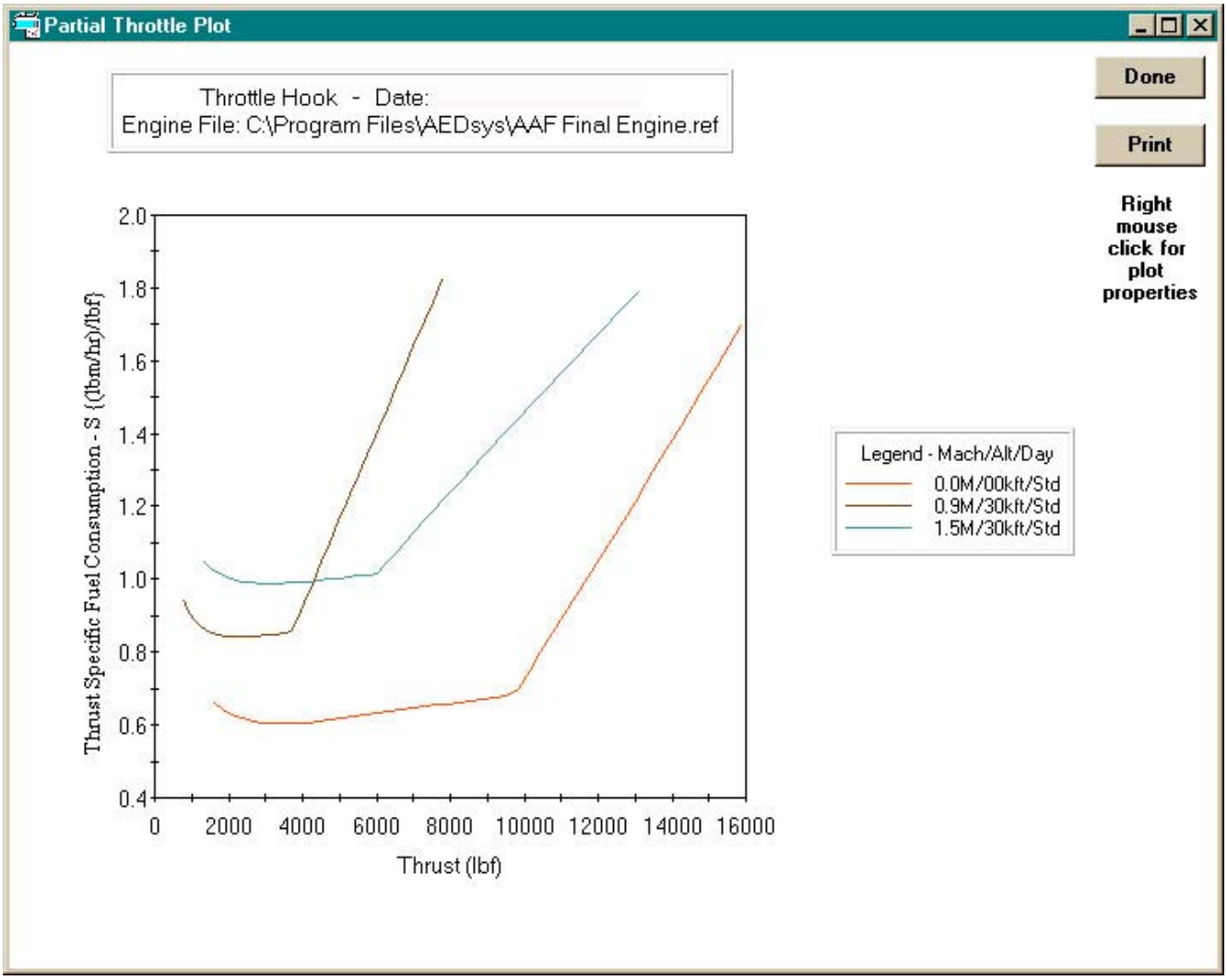


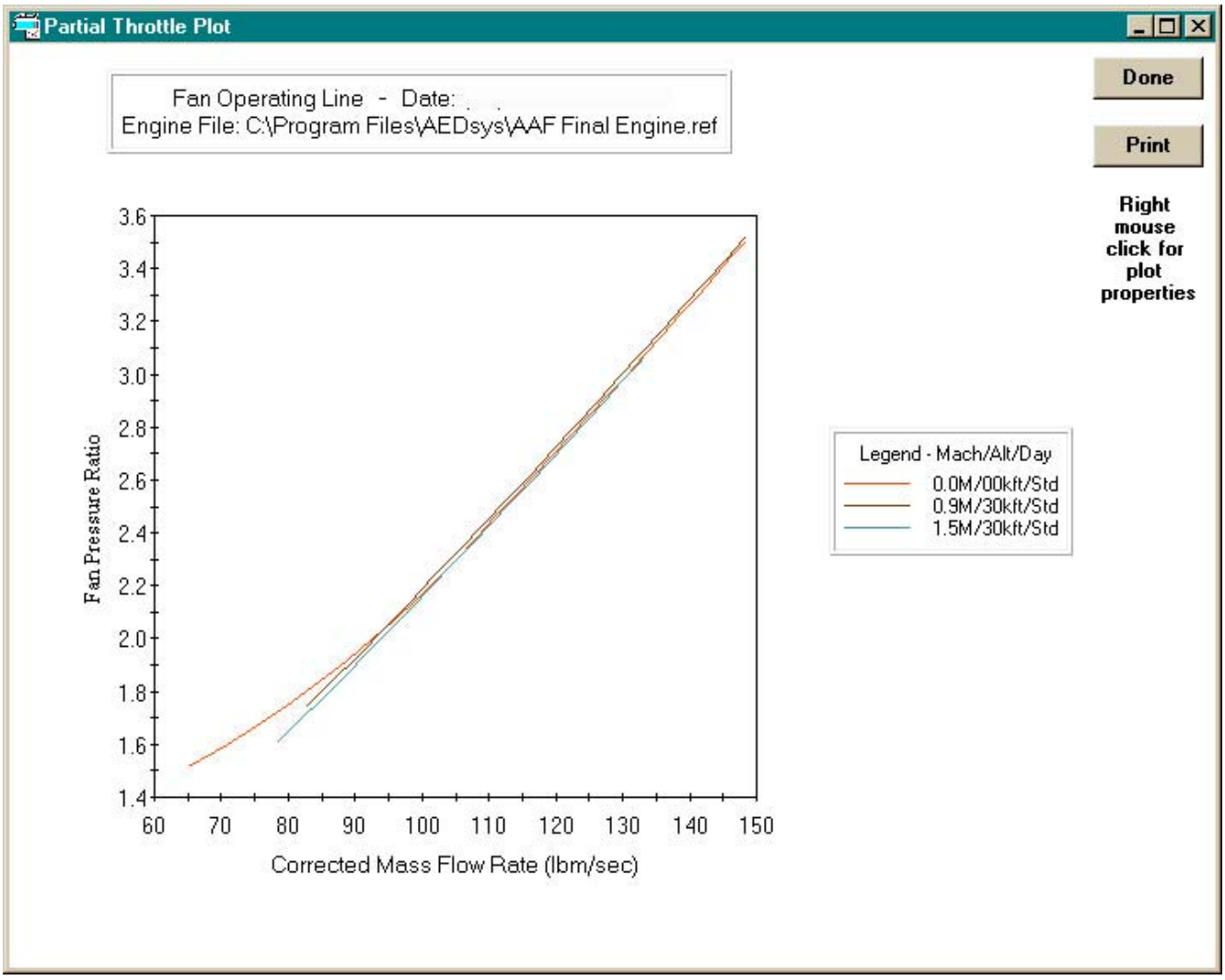


Once the partial throttle has been calculated, the partial throttle plot buttons become visible in the lower right of the engine test window as shown below.



As an example, the partial throttle performance was calculated at the following altitude/Mach number conditions in a standard altitude: 0 kft/0.0M, 30 kft/0.9M, and 30 kft/1.5M. The uninstalled throttle hooks (thrust specific fuel consumption versus thrust) are displayed below and the fan operating line is shown on the next page.

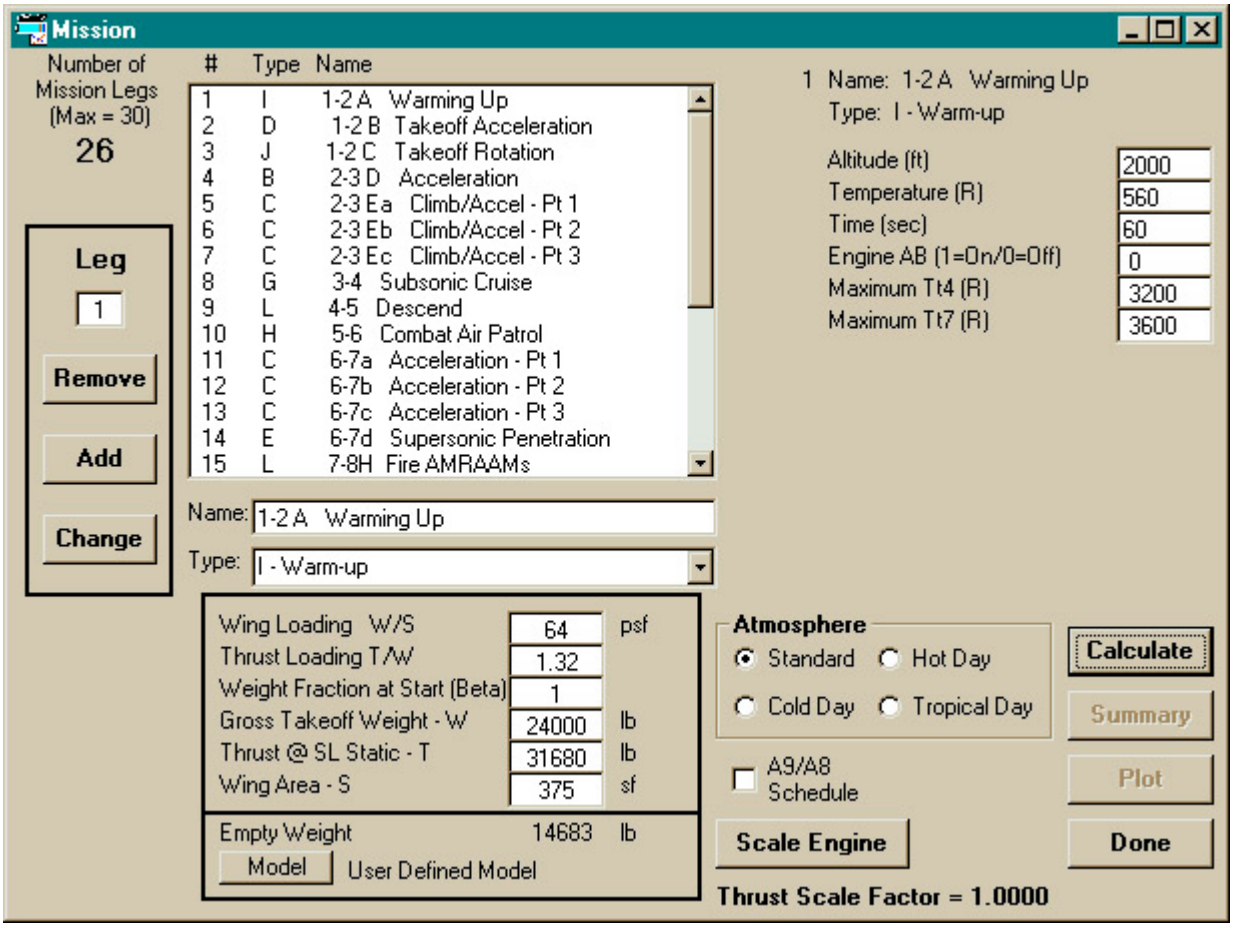



Partial Throttle Plot
Fan Operating Line - Date: . .
Engine File: C:\Program Files\AEDsys\AAF Final Engine.ref
Done
Print
Right mouse click for plot properties
Fan Pressure Ratio
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
60
70
80
90
100
110
120
130
140
150
Corrected Mass Flow Rate (lbm/sec)
Legend - Mach/Alt/Day
0.0M/00kft/Std
0.9M/30kft/Std
1.5M/30kft/Std

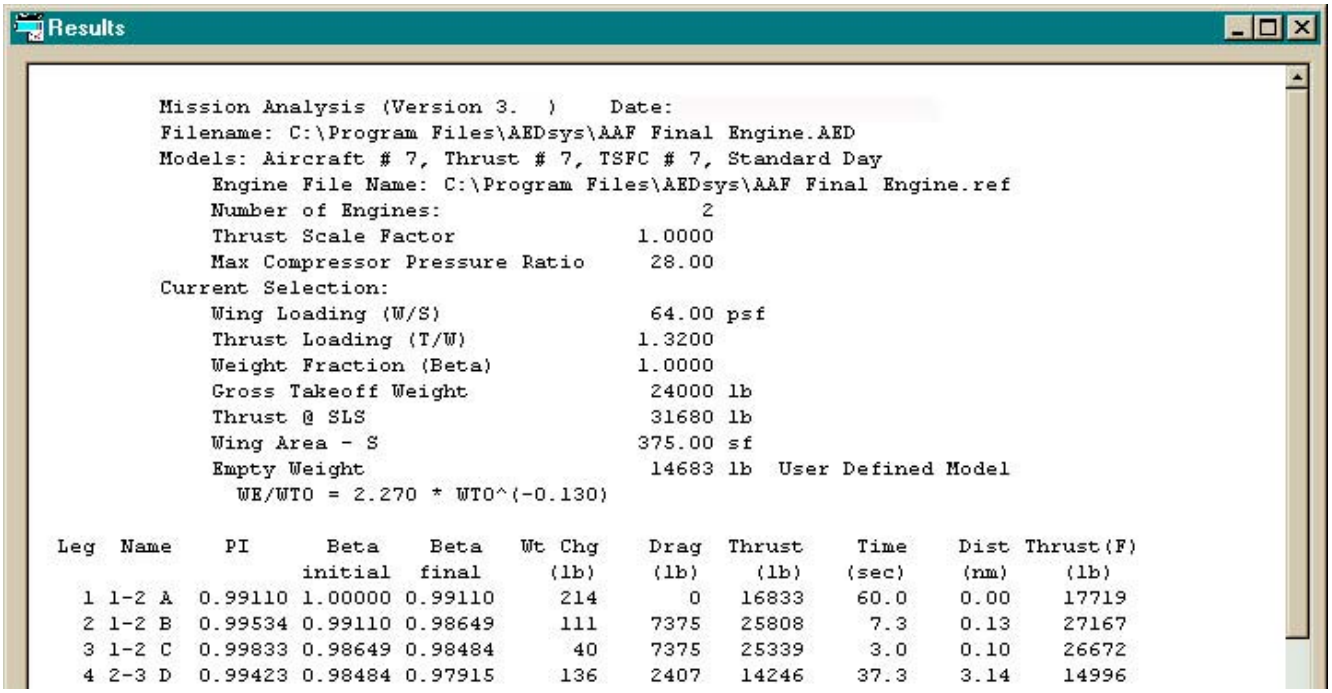
9. ENGINE CYCLE DECK MODEL – MISSION ANALYSIS

Once a reference engine data has been input into the AEDsys program and the installation loss model selected in the Engine Test window, mission analysis can be performed of the reference engine installed in the aircraft. Pressing the **Mission** button on the AEDsys main window opens the Mission window, shown below. Note that the mission leg data now has maximum T_{t4} (and T_{t7} when applicable) for each mission leg. This data needs to be set to the appropriate maximum(s) for each mission leg.

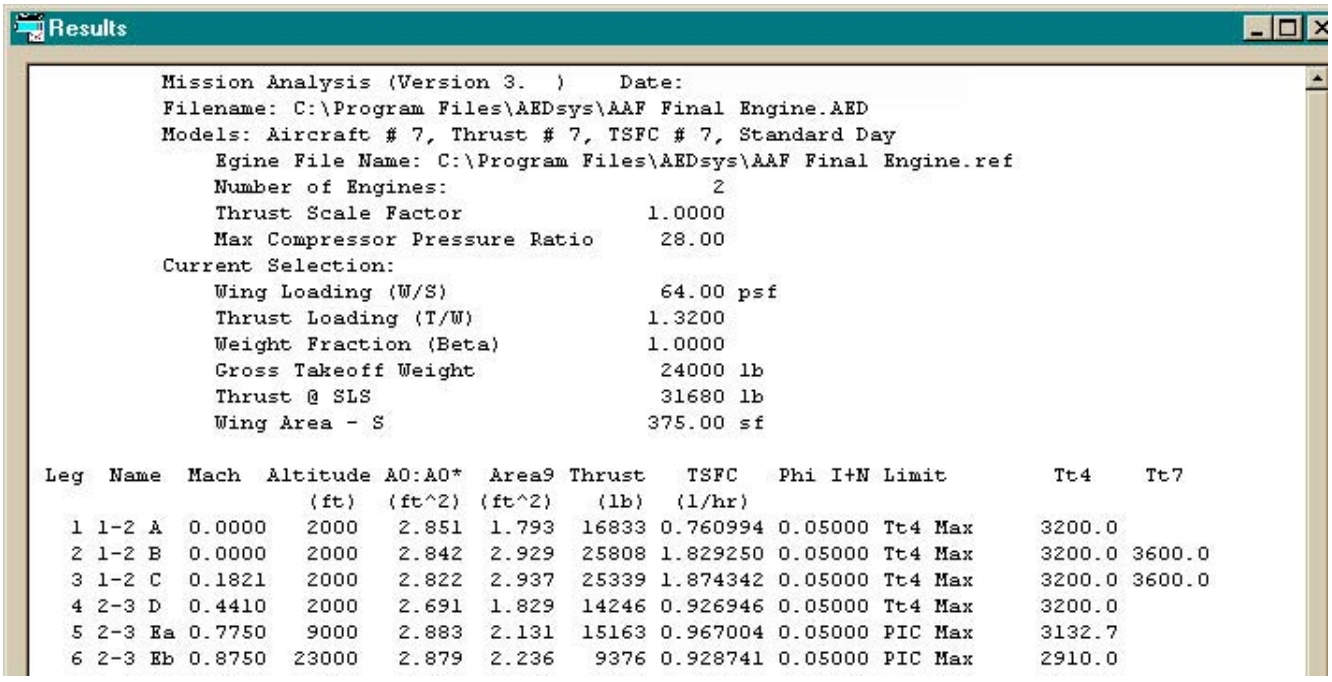
For engines with convergent-divergent exhaust nozzles, an exit area (A_9/A_8) schedule can be input versus Mach number during the exhaust nozzle design. It is not recommended to select the A_9/A_8 schedule until that phase of the design.



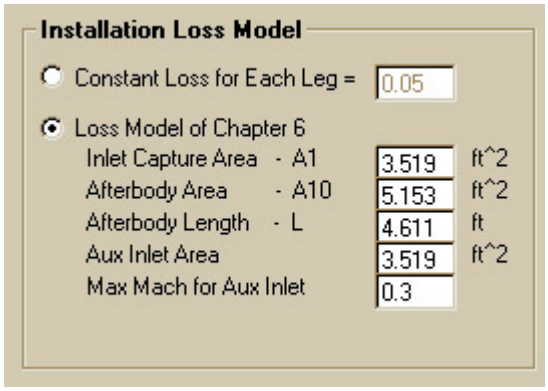
The mission summary for a cycle deck engine has two pages. The first page (shown below for a constant installation loss model) is similar to that of the simple engine models. Information about the number of engines, thrust scale factor, and engine controls is now included in the header. In addition, a column listing the uninstalled thrust (F) has been added to the right of the previous columns of data.


Results
Mission Analysis (Version 3.) Date:
Filename: C:\Program Files\AEDsys\AAF Final Engine.AED
Models: Aircraft # 7, Thrust # 7, TSFC # 7, Standard Day
Engine File Name: C:\Program Files\AEDsys\AAF Final Engine.ref
Number of Engines: 2
Thrust Scale Factor 1.0000
Max Compressor Pressure Ratio 28.00
Current Selection:
Wing Loading (W/S) 64.00 psf
Thrust Loading (T/W) 1.3200
Weight Fraction (Beta) 1.0000
Gross Takeoff Weight 24000 lb
Thrust @ SLS 31680 lb
Wing Area - S 375.00 sf
Empty Weight 14683 lb User Defined Model
WE/WTO = 2.270 * WTO^(-0.130)
Leg Name PI Beta initial Beta final Wt Chg (lb) Drag (lb) Thrust (lb) Time (sec) Dist (nm) Thrust(F) (lb)
1 1-2 A 0.99110 1.00000 0.99110 214 0 16833 60.0 0.00 17719
2 1-2 B 0.99534 0.99110 0.98649 111 7375 25808 7.3 0.13 27167
3 1-2 C 0.99833 0.98649 0.98484 40 7375 25339 3.0 0.10 26672
4 2-3 D 0.99423 0.98484 0.97915 136 2407 14246 37.3 3.14 14996

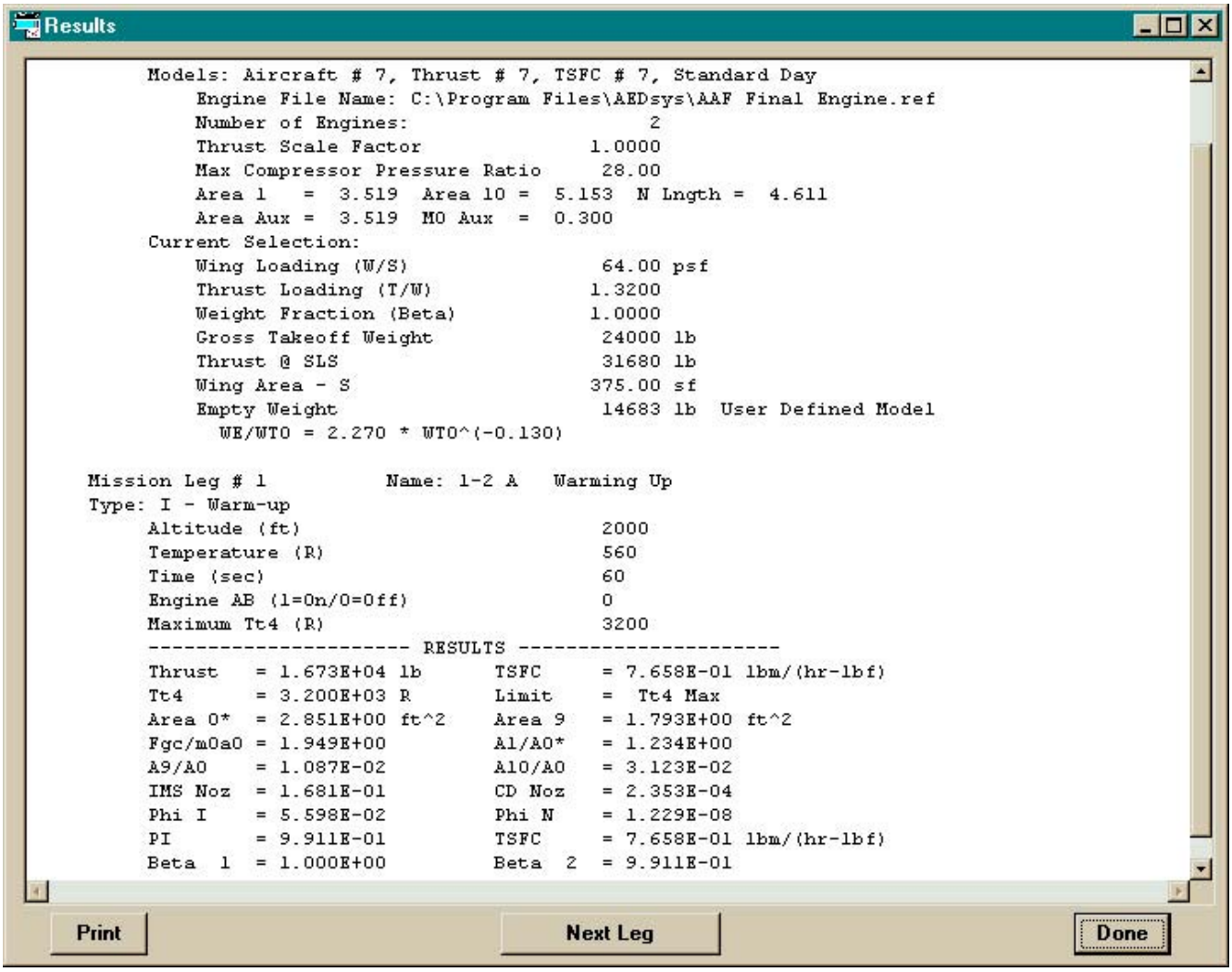
The second summary page lists the required A_0* (or A_0) and A_9 areas, TSFC, installation loss, control limit, maximum engine temperatures, etc. This area data is very useful for sizing the inlet (A_1) and the afterbody (A_{10}).


Results
Mission Analysis (Version 3.) Date:
Filename: C:\Program Files\AEDsys\AAF Final Engine.AED
Models: Aircraft # 7, Thrust # 7, TSFC # 7, Standard Day
Egine File Name: C:\Program Files\AEDsys\AAF Final Engine.ref
Number of Engines: 2
Thrust Scale Factor 1.0000
Max Compressor Pressure Ratio 28.00
Current Selection:
Wing Loading (W/S) 64.00 psf
Thrust Loading (T/W) 1.3200
Weight Fraction (Beta) 1.0000
Gross Takeoff Weight 24000 lb
Thrust @ SLS 31680 lb
Wing Area - S 375.00 sf
Leg Name Mach Altitude (ft) A0:A0* (ft^2) Area9 (ft^2) Thrust (lb) TSFC (1/hr) Phi I+N Limit Tt4 Tt7
1 1-2 A 0.0000 2000 2.851 1.793 16833 0.760994 0.05000 Tt4 Max 3200.0
2 1-2 B 0.0000 2000 2.842 2.929 25808 1.829250 0.05000 Tt4 Max 3200.0 3600.0
3 1-2 C 0.1821 2000 2.822 2.937 25339 1.874342 0.05000 Tt4 Max 3200.0 3600.0
4 2-3 D 0.4410 2000 2.691 1.829 14246 0.926946 0.05000 Tt4 Max 3200.0
5 2-3 Ea 0.7750 9000 2.883 2.131 15163 0.967004 0.05000 PIC Max 3132.7
6 2-3 Eb 0.8750 23000 2.879 2.236 9376 0.928741 0.05000 PIC Max 2910.0

The mission performance of a cycle deck engine with the inlet and afterbody sized using the methods of Chapter 6 can be determined similar to the above analysis for constant installation loss. Based on the previous type of mission analysis, the Chapter 6 model inlet and afterbody data is first entered into the appropriate data fields on the Engine Test window (see below) before the mission analysis is performed.


Installation Loss Model
Constant Loss for Each Leg = 0.05
Loss Model of Chapter 6
Inlet Capture Area - A1 3.519 ft^2
Afterbody Area - A10 5.153 ft^2
Afterbody Length - L 4.611 ft
Aux Inlet Area 3.519 ft^2
Max Mach for Aux Inlet 0.3

The first page of the results and the top of the two summary pages now display the inlet and afterbody information as shown below for the first results page. The Results window for each mission leg now gives the data used to calculate the installation losses and the results.


Results
Models: Aircraft # 7, Thrust # 7, TSFC # 7, Standard Day
Engine File Name: C:\Program Files\AEDsys\AAF Final Engine.ref
Number of Engines: 2
Thrust Scale Factor 1.0000
Max Compressor Pressure Ratio 28.00
Area 1 = 3.519 Area 10 = 5.153 N Lngth = 4.611
Area Aux = 3.519 M0 Aux = 0.300
Current Selection:
Wing Loading (W/S) 64.00 psf
Thrust Loading (T/W) 1.3200
Weight Fraction (Beta) 1.0000
Gross Takeoff Weight 24000 lb
Thrust @ SLS 31680 lb
Wing Area - S 375.00 sf
Empty Weight 14683 lb User Defined Model
WE/WTO = 2.270 * WTO^(-0.130)
Mission Leg # 1 Name: 1-2 A Warming Up
Type: I - Warm-up
Altitude (ft) 2000
Temperature (R) 560
Time (sec) 60
Engine AB (1=On/0=Off) 0
Maximum Tt4 (R) 3200
---------- RESULTS ----------
Thrust = 1.673E+04 lb TSFC = 7.658E-01 lbm/(hr-lbf)
Tt4 = 3.200E+03 R Limit = Tt4 Max
Area 0* = 2.851E+00 ft^2 Area 9 = 1.793E+00 ft^2
Fgc/m0a0 = 1.949E+00 A1/A0* = 1.234E+00
A9/A0 = 1.087E-02 A10/A0 = 3.123E-02
IMS Noz = 1.681E-01 CD Noz = 2.353E-04
Phi I = 5.598E-02 Phi N = 1.229E-08
PI = 9.911E-01 TSFC = 7.658E-01 lbm/(hr-lbf)
Beta 1 = 1.000E+00 Beta 2 = 9.911E-01
Print
Next Leg
Done

The first and second mission summary pages for the installation loss model of Chapter 6 is very similar to those of the constant installation loss model with the exception of the additional information in the header. The second mission summary page is presented below for the AAF showing the variation in installation losses with flight condition.